modern SCIENCE

n OUR ENVIRONMENT

modern SCIENCE in our environment

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Preface

PERHAPS the pupil who is beginning his science study is not unlike the great Sir Isaac Newton, who said: "I seem to have been only like a boy playing on the seashore, diverting myself with now and then finding a prettier shell or a smoother pebble than ordinary, whilst the great ocean of truth lay undiscovered before me." One of the aims of this science series is to distill for beginners a few drops from that vast ocean of truth.

The early explorers sailed their wooden vessels to their limited "four corners of the globe." Today the modern explorer flies in speedy planes from continent to continent or on a journey completely around the earth.

The beginner in science too is an explorer. He roams the earth in his journeys, even delving beneath its surface to search out its treasures. He pauses from time to time to become acquainted with the plants he sees or to make friends with the animals he meets. He searches living cells by microscope and test tube. He finds how utterly dependent man is upon both plant and animal life for food, shelter, clothing, and other necessities. If he journeys by water, he is borne by the tides, tossed by the waves, and driven by the winds. He may leave the earth and sail off in a gondola beyond the clouds and storms of the troposphere into the peace and quietude of the stratosphere. In his imagination, he rides with Mercury to follow that mighty hunter, Orion, as he and his dogs chase ancient Taurus, the Bull, over the western horizon.

But our science pupil will not be content with visions only of largeness. The microscope reveals a swarm of living organisms in a drop of water, some of which may mean life

or death for human beings. The atoms of the chemist and the molecules of the physicist must intensify the pupil's interest in the Lilliputian world revealed by test tube and microscope.

In this series of books the authors have attempted to do more than give to the pupil a picture of the world about him. It is to be hoped that he will really get acquainted with some of the laws of nature, that he will be curious to learn what makes things work, and that his science study will give him an assurance that things do not just happen, but that there is an underlying cause for every effect. Thinking can be scientific. Much needless worry can be avoided, and much money can be saved, if charms, omens, and superstition can be supplanted by scientific reasoning.

Only by a study of his environment and his relation to it can a pupil learn to take care of his own dwelling house and keep both his body and mind in excellent health. By such study he learns why we behave as we do, and why co-operation is better than competition.

In studying science, the pupil may derive great satisfaction from a study of what man has accomplished. He learns how and why man makes machines, how man uses natural light and how he makes artificial light, how he heats his home in cold weather, and how he has harnessed electricity to make it do his bidding. The pupil learns also how far man has progressed in the fields of medicine and surgery, and in the study of heredity.

In the first book of this series, the authors aim to familiarize the pupil with his environment. In the fall when flowers, leaves, seeds, and fruits are in season, the pupil is introduced to the plants and animals of his neighborhood. Then he learns something of the importance of the water cycle in its relationship to plants and animals. He learns, too, that the air which he breathes is a real substance, without which neither fire nor life is possible. The earth, he finds, has suffered many changes in the formation of mountains and val-

leys and in the making of soil. Finally, in the spring he studies plants and animals again. This time he studies their methods of development and their relation to man, and the importance of conservation.

The authors have tried at all times to use simple sentences, with a vocabulary that can be easily comprehended by seventh-grade pupils. Unless some new words are given, however, there will be no growth. Therefore, a vocabulary containing useful new words, or familiar words used with new meanings, is given at the beginning of each chapter. These words are italicized the first time that they appear in the text. Other words which might be new to the pupil are defined in the context, and their pronunciations are given.

Obviously no science can be presented without a foundation of factual material. Such material is included in this book, but much stress has been placed, too, upon developing scientific attitudes, scientific methods of approach, and scientific habits of thinking.

No separate unit is made of the important work of conservation. It is the opinion of the authors that the need for conservation of our natural resources can best be stressed in several different ways, and that the very repetition of the topic in its several aspects serves to give greater emphasis.

Each chapter is introduced by some interest-arousing questions. In order to make assignments easy and to make cross references possible, the sections are numbered. Each section is headed with a question which supplies the student with a key to the topic. Some sections, marked with a star, are optional. Each diagram and picture is integrated with the text by a reference at the point illustrated. A list of practical and thought-provoking questions is given at the end of each chapter. Here, too, are included interesting suggestions for pupil activities.

The Authors

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HAVE you ever wondered why Admiral Byrd explores the South Pole? He has to spend months in preparing for one of his expeditions. He must get his equipment ready; lay in large supplies of food; plan to take care of his dogs; and choose hardy, reliable men for his party. Then he sails off, keeping on southward until he reaches the icy regions that fascinate him.

Why do they fascinate him? Has he really learned to talk with the penguins in the Antarctic? Is it, most of all, his love for exploring that sends him on these long, difficult journeys?

Some persons are stay-at-homes, willing to let others blaze trails into unknown or unfamiliar places. But most of us want to explore.

You can embark on an expedition of your own: you can explore the fields of science. The book which you are beginning to study is a gateway through which you will pass into the highways and byways of scientific knowledge.

As you explore, you will examine new plants and new flowers; strange animals will cross your path. You may have pleasant weather or encounter hurricanes. You will dig into the earth for treasure. You will stop sometimes to make sure that you are fitted for the next journey. You will marvel at the things that people have learned since the Dark Ages.

Think about these!

1. Would you be the thirteenth person to sit down at a table?
2. Do you think that a scientist fears Friday the thirteenth?
3. Are you as curious about things as you were when you were seven years old? Have you learned more since then than before?
4. What do you consider your most important ways of getting knowledge?

Words for this introduction

Environment (ĕn·vī′rŭn·mĕnt). All the surrounding conditions or influences that affect the life of the individual.
Classify. To arrange in an orderly manner in sets or groups.
Experiment (ĕks·pĕr′ĭ·mĕnt). A test or trial to learn the truth about something of which we are ignorant, uncertain, or doubtful.
Microscope (mī′krō·skōp). An instrument by means of which small things are magnified.
Planet. A heavenly body that revolves around the sun.
Matter. Anything that takes up room or occupies space.
Substance. The material of which a thing is made.
Psychologist (sī·kŏl′ō·jĭst). A person who is skilled in the science dealing with the study of the mind.
Philosopher (fĭ·lŏs′ō·fĕr). A thinker who seeks causes and relationships.
Incandescent (ĭn′kăn·dĕs′ĕnt). Heated until there is a glow.
Superstition (sū′pĕr·stĭsh′ŭn). A mistaken belief; or an excessive fear of, or reverence for, the unknown or the mysterious.

INTRODUCTION

Exploring the Fields of Science

1. Is nature poor or rich? Millions of stars send their light to the earth from tremendous distances. They have been giving off light for millions of years. The sun gives us its glorious light by day. At night, as the moon passes through its different phases, or changes, it gives us silver light. When the moon is full, it is so beautiful that we understand why savage tribes often worshiped it. The name *Mazda,* used for some electric-light bulbs, comes to us from the name of the Persian sun god.

The mighty oceans are so vast and so extensive that they fill us with awe. We become aware of their greatness as we sit on the seashore and watch the huge waves come rolling onward toward the shore, and when we watch the tides as they ebb and flow twice every twenty-four hours. [See Fig. 1.]

The mountains rise like giants above the plains. Huge forces sometimes work to raise or push them higher and higher. On the other hand, the winds, the snow and ice, and the running water are slowly but constantly tearing down

the hills and mountains and carrying the fragments to the sea. The earth itself is a huge treasure house from which men get coal, oil, sand, clay, iron, copper, silver, gold, and various other riches.

Plants in almost endless number and variety grow upon the earth. They produce their leaves, their flowers, their fruits, and their seeds in their seasons. Grasses cover the earth with a carpet of green. The plants in the jungles grow in such great abundance that one cannot penetrate tropical forests without cutting a path through them. [See Fig. 2.]

We may think of nature as being wasteful when we see large flocks of birds, large herds of deer or antelope, or huge droves of other kinds of animals. [See Fig. 3.] There are several hundred thousand varieties of insects. Some of them are so numerous that they even threaten to cause certain plants to die out. Hordes of insects sometimes devour so much of a farmer's crops that the farmer is in danger of famine.

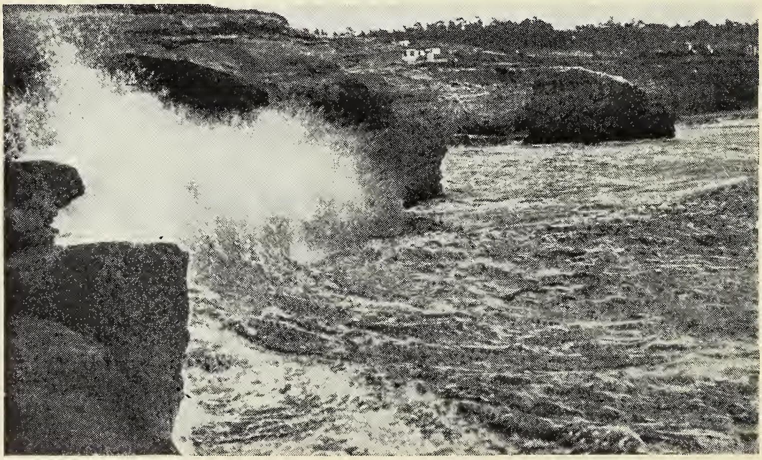


FIG. 1. There is nothing in the world more treacherous than a stormy sea. Man is often powerless against its strong tide and currents. (*Philip D. Gendreau*)

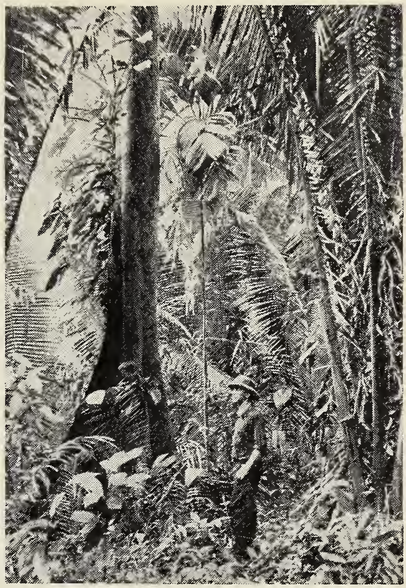


FIG. 2. These towering palms grow in the dense, tropical Central American jungle. Notice the size of the man in comparison with that of the trees. In some tropical forests, vines grow over the trees and mat them together so completely that it is almost impossible for a man to enter the forest unless he has a huge knife to cut away the plant growth. (*Ewing Galloway*)

Our neighbors, too, have multiplied until the problem of securing food, clothing, and shelter for the 2,000,000,000 persons on the earth has become increasingly difficult. Many wars have been fought between different races and nations in efforts to gain control of mineral wealth, forests, or farm lands. In most cases wars have not helped much toward solving the problem. One nation may win and enlarge her boundaries, and then in a few years she may have to go to war again in an effort to keep her territory.

2. Where do you fit into this picture? As you begin your study of science, you must be like the merchant who takes an *inventory* (ĭn′vĕn·tō′rĭ) — a catalogue or list of property or things. You must look about you and see what there is in stock, just as Robinson Crusoe took stock of his possessions when he found himself shipwrecked on a desert island. The aim of this book is to make you familiar with your *environment*. You will learn something of the water that covers a

large portion of the earth, and of the air which covers both the water and the land. You will learn something of the vast treasures that lie buried in the earth itself. You will find out how man learned to use fire to keep himself warm in winter, to supply himself with power, and to forge some of the metals which he uses as tools. Some units in this book will give you a knowledge of the plants and animals which are your neighbors, and of their usefulness to man.

In a book prepared for your later study, you will learn how to use the things which nature supplies so plentifully, and how to adapt them to your personal needs. You will learn how the human body, which is a perfect machine, is dependent upon air and water, upon animals and plants, and upon the other treasures which nature so abundantly supplies. You will learn something about the human body and how it works, how it is clothed and protected, and how it can be kept in good health.

FIG. 3. Can you count them? Australia is a great sheep-growing country. (*Courtesy Australian News and Information Bureau*)

Robinson Crusoe was not content merely to live on the food which he saved from the wrecked ship. He tried to improve his environment by inventions. Civilized man is seldom content merely to take his food, make his clothing, and build his home. He too attempts to improve upon his environment. He invents machines of all kinds to make his work easier. He builds railways and concrete highways. He manufactures steamboats, locomotives, and automobiles to provide means for rapid transportation. In order to communicate with his neighbors, he has invented the telegraph, the ocean cable, the telephone, and the radio. He looks to science to cure his ills, to increase his enjoyments, and to help him to live longer. Later in your study of science you will learn something of the ways in which civilized man has learned to improve upon and to control natural conditions to his own advantage.

3. What do we mean by "science"? The word *science* comes from the Latin word *scientia* (sī·ĕn′shĭ·*ȧ*), which means *knowledge.* Therefore we shall expect our study of science to give us a better understanding of some of the facts and laws of nature. But mere knowledge of isolated facts is not science. The scientist will *classify* his knowledge and

Fig. 4. Apple blossoms (left) are related to raspberry blossoms. (*Left, Topp from Monkmeyer; right, U. S. Dept of the Interior*)

try to learn how one set of facts is related to another set.

Just as a librarian arranges books of fiction on one set of shelves, law books on another, books of biography on a third, and books that deal with the study of animals on a fourth, so the scientist groups his facts and classifies them under general truths and laws. The careless observer does not notice that the wild rose, the pear, the apple, and the strawberry are much alike. The next time you have an opportunity to compare the flowers of two or more of these four plants, you may be able to tell why the *botanist* groups them all in the rose family. [See Fig. 4.] If you can, examine the teeth of such animals as the mouse, the rat, the rabbit, the squirrel, the woodchuck, and the beaver. Can you understand now why the *zoologist* (zȯ·ŏl′ȯ·jĭst) groups such animals under one order known as *rodents,* or *rodentia* (rȯ·dĕn′shĭ·ȧ), which comes from the Latin word *to gnaw?* [See Fig. 5.]

The scientist does more than observe carefully and then classify his knowledge. He challenges mere opinions. Then he plans *experiments* in his efforts to find out the truth. He gives up his ideas if he finds that they are wrong. He believes that there is a cause for everything and that things do

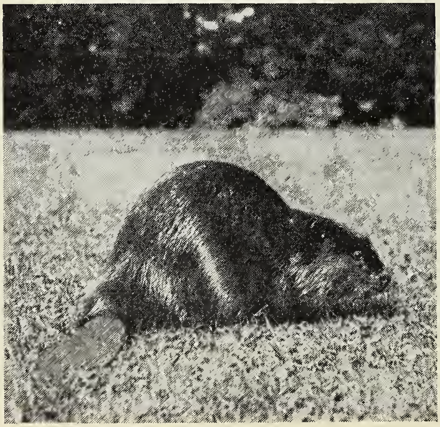


FIG. 5. The beaver is so industrious that the expression "work like a beaver" is very common. Beavers gnaw all the way around a tree, until finally the tree is so weakened that it will fall down. In such a manner, beavers cut logs to dam up streams and make the lakes in which they build their homes. (*Courtesy U. S. Department of the Interior*)

not "just happen." He tries to form scientific habits of thinking, questioning his own ideas and those of others, and trying to learn the truth.

4. Why are there so many sciences? There is such a vast store of scientific knowledge that it is not possible to group everything under one heading. There are many special sciences, of which we shall mention a few.

Botany is a special science which deals with the study of plant life. Hundreds of thousands of plants are known. No botanist can hope to live long enough to learn all about roots, stems, leaves, flowers, and fruits. Many plants are so tiny that they can be studied only with the aid of a powerful *microscope.*

Zoology (zō̇·ŏl′ō̇·jĭ) is the science that deals with the study of animals, of which there are many thousands of different kinds. One might devote his whole lifetime to the study of insects alone, because there are several hundred thousand kinds known. In fact there is a branch of zoology devoted solely to the study of *insects.* It is called *entomology* (ĕn′-tō̇·mŏl′ō̇·jĭ). A special branch of zoology deals with the study of *birds;* another branch deals with the study of *reptiles;* and another branch deals with the study of *fishes.*

Astronomy (ă̇s·trŏn′ō̇·mĭ) is a science which deals with the study of stars and other heavenly bodies. You probably know Venus as an evening "star" through several months of the year. Perhaps you sometimes get up early enough to see it as a morning "star." Possibly you have learned how to identify Mercury, Mars, and Jupiter. The astronomer calls such heavenly bodies *planets.* They are not true stars. They revolve around the sun just as our earth does. [See Fig. 6.]

We could add to the list such sciences as *biology, physics, chemistry, physiology* (fĭz′ĭ·ŏl′ō̇·jĭ), *medicine, meteorology, geology,* and many others. In order not to heap up too big

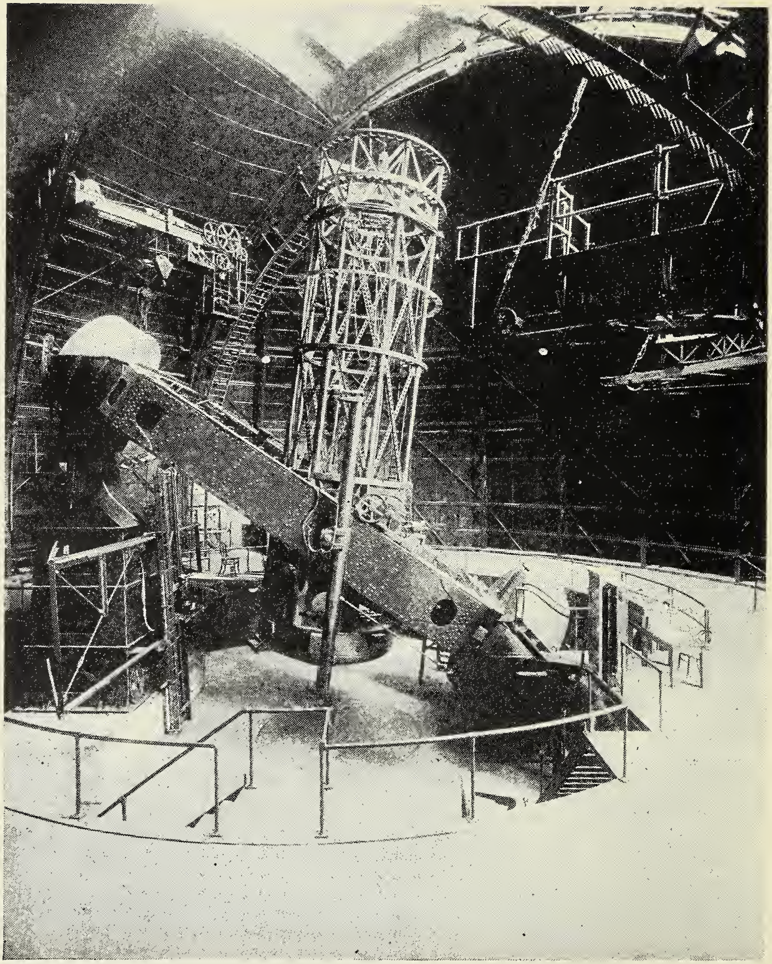


FIG. 6. The mirror in the Mount Wilson reflecting telescope is 100 inches (8 feet, 4 inches) in diameter. It magnifies heavenly bodies and makes them seem closer to the observer than they are. With the aid of such a telescope, men can photograph stars which are too far away to be seen by the naked eye. The planets, too, seem nearer to us when viewed with a telescope. (*Courtesy Mount Wilson Observatory*)

a list, we shall not attempt to mention any more, although it would be possible to make another list of even greater length.

5. What journeys into science shall we take? In our excursions into the fields of science, we cannot expect to study any one science in great detail. We are *explorers*. In some cases we shall get only a bird's-eye view; in other cases we shall peer more closely. We shall get glimpses of the sciences mentioned in the preceding section. We shall also look into the science of *physiography* (fĭz′ĭ·ŏg′rȧ·fĭ), which deals with the surface of the earth, and tells how the features of the earth are being changed by winds, running water, volcanoes, earthquakes, glaciers, and the waves of the ocean.

We shall take a journey into *biology,* that science which deals with all living things. It includes the study of both plants and animals. We shall expect, too, to learn something of human *anatomy* and *physiology*. We need to learn how our bodies work, and how we may best take care of them.

Mark Twain is reported to have said: "Everybody talks about the weather, but nobody does anything about it." If we are to talk intelligently about the weather, we must at least take a side trip into *meteorology*, that science which deals with the weather. We shall study weather indications and learn to be to some extent weatherwise.

In studying *chemistry* we find out what things are made of. *Matter* is the name given to such material. We also learn about the changes that take place in matter. Chemists help to make our drugs and medicines, our iron and steel, our dyes and paints, our soap, and thousands of other products which we use every day. Would you not be interested in paying the chemist a call as we make our journeys through the fields of science? [See Fig. 7.]

In the study of *physics,* we find many familiar topics. They include *heat, light, sound, machines,* and *electricity.*

We must learn something of heat when we find out how our houses are heated. We have windows in our homes to permit sunlight to enter. We have many machines that we use to help us in our work both inside and outside the home. Are you not interested in learning something about how they work? We all like to talk, and most of us are fond of music. Therefore we must stop long enough to come to be "on speaking terms" with sound. We use electricity to light our homes, to run our vacuum cleaners and our washing machines, to operate our electric fans, to heat our toasters and percolators, and to furnish current for our radios. It is a very useful force and well worth a fairly long stop in our journey.

6. What five gateways to knowledge have you? At the age of four or five months you made a great discovery. You found that your hands and fingers belong to you. From that

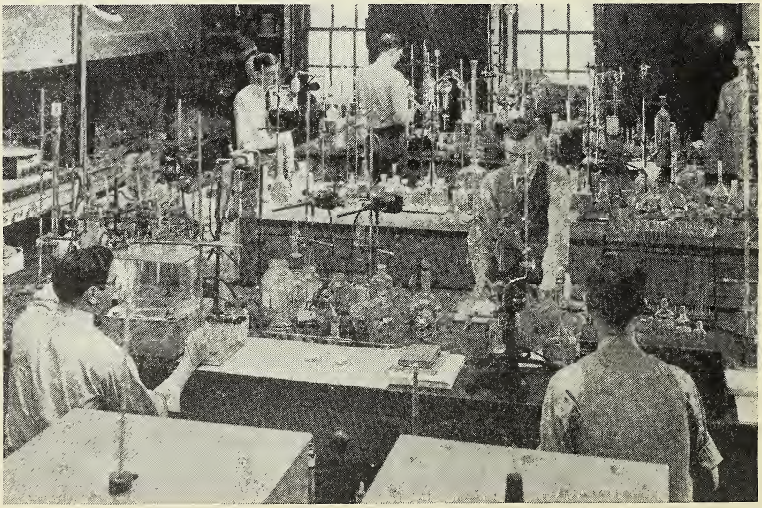


Fig. 7. In such a chemical laboratory the chemist works with beakers, flasks, test tubes, retorts, and stills in his efforts to pry into nature's secrets. (*Courtesy du Pont Co.*)

time, you began to notice things about you. You learned many things about your surroundings by using your eyes as *gateways to knowledge.* You kept looking about you, studying everything in your neighborhood or environment.

A little girl slightly less than three years of age stood looking at the moon. She said, "The moon has a dirty face; it has egg on its face. I'll go and wipe it off. It's just across the street." She had learned to use her eyes, but she had not yet learned to judge size or distance. A baby may reach for the moon and cry because he cannot get it. When you were five or six years old, you learned how to use your eyes to read; in doing so, you broadened one of the important gateways to knowledge.

Some persons argue that our ears are even more useful to us than our eyes. Such an argument is foolish, because the loss of either our eyes or our ears is a great misfortune. We learn many things by being told. A person who listens attentively is likely to gain much knowledge. In this machine age, there are so many labor-saving devices that we have more time for leisure than our parents had. We can derive pleasure from listening to good music. We may even make music our hobby. We need our ears, too, to warn us of approaching danger. [See Fig. 8.]

The sign "Please do not handle" shows how much we depend upon the sense of touch as a gateway to knowledge. It is difficult to follow the rule of "hands off," because we learn by touch whether an object is hard or soft, smooth or rough, regular or irregular in shape, dry or moist, and hot or cold. We gain an idea of distance as we reach for an object, and we learn to judge its weight by the amount of effort needed to lift it.

Suppose you permit yourself to be blindfolded, and let someone test your sense of smell by holding various things

Fig. 8. Many unnecessary accidents happen to persons who pay no attention to warning signals such as the one shown in this picture. At such crossings, a flashing red light warns the driver of an oncoming automobile that a train is approaching. Often a bell or gong also is used to warn automobile drivers of danger. Thus the driver receives warnings from both his eyes and ears. (*Pennsylvania Railroad Photo*)

beneath your nostrils. You may be astonished to learn how small is the number of things you can identify by their odors. You probably will have no trouble in recognizing vinegar, coffee, fuel gas, ammonia, fresh paint, oranges, and possibly a dozen or so other things. If, however, you do not mistake many common *substances,* then your sense of smell is keener than that of the average person. Too often the statement that " Your nose knows " is not true. But your sense of smell may be a fourth gateway to knowledge.

Your sense of taste is a fifth gateway to knowledge. It enables you to tell whether a substance is sweet or sour, and whether it is salty or bitter. It may prove very dangerous to use the sense of taste in trying to learn what a substance is, and in many cases the sense of taste is not very reliable anyway. We enjoy eating many foods, not because they have a pleasing taste, but because their odor is pleasing. We often mistake odor for flavor. We realize the truth of this better when a severe cold dulls our sense of smell. Then we

sometimes say that our food does not "taste good." If you wish to experiment, you may close your eyes and hold your nose while someone feeds you samples of different kinds of foods. Under such conditions, can you tell roast beef from chicken?

7. How can you sharpen your senses? Are you a good observer? You have seen cows. Are a cow's ears in front of her horns, or are they behind her horns? Can you tell whether they are above or below the horns? If you have ever drawn a picture of a cow, you can probably answer the question correctly. Most artists are good observers. Have you ever played with a cat? How many toes has a cat? Is the number on each front foot the same as that on each hind foot? Can you tell whether the numbers on the dial of your watch are Arabic or Roman? Can you tell whether the bases of all those numbers are toward the center of the dial or toward the outside, or whether they vary in position? Is there a *6* on the face of your watch? Think of some person you know well. Try to describe him accurately. Can you give the color of his hair and of his eyes? Can you describe his features so definitely that a stranger could pick him out of a group?

A *psychologist* once said: "Interest is the mother of attention, and attention is the mother of memory. If you would have a good memory, secure both her mother and her grandmother." Try the following experiment. Ask someone to place two dozen or more different objects on a large table. Walk slowly around the table, step into the next room, and then write from memory the names of as many of the objects as you can remember. If you repeat such an experiment every day for a month, you will find out how much your ability to observe objects has improved. You may try the experiment, too, by walking past the display window of a store

and testing yourself to find out how well you observed. Because of his special training, a football coach or scout sees plays made in the line that the ordinary spectator misses.

Are your ears trained? Can you name or recognize the tunes you hear on the radio? Can you tell by ear what note is played on a piano? Can you recognize a person by his voice? The doctor learns the condition of your heart and lungs by listening to your heartbeats and to your lungs as you breathe. He uses an instrument called a *stethoscope* (stĕth′ō·skōp) to make the sounds louder. Thomas A. Edison was very hard of hearing, but he was a good judge of phonograph records. He could hear better when he rested his head against the phonograph case. The sounds were conducted through the bones of his head, and he could easily pick out defects in the records. He had trained his ears.

Can you reach into your pocket and pick out a nickel, a cent, or a dime without making a mistake? That would be easy for a blind man. He has trained his fingers so that he can almost see with them. If you have read about Helen Keller, you must have marveled at her ability to make three gateways to knowledge do the work of five. As we watch a blind man tuning a piano, weaving a basket, or reading *Braille* (brāl) — a system of printing for the blind in which characters are represented by raised dots — we learn that careful and continued practice sharpens the senses.

A dog can recognize his master by the sense of smell. He tracks animals by the same method. [See Fig. 9.] Bloodhounds have a very keen sense of smell. For that reason they are sometimes used to track or follow criminals. A doctor, a druggist, or a chemist is likely to have a well-developed sense of smell.

Could you earn your living as a taster? Some men do. They become professional tea tasters or coffee tasters. Their

FIG. 9. Irish setters are valuable hunting dogs. The setter in this picture is sniffing the air hoping to find a scent to follow. The hunter depends upon the keen sense of smell of a setter or pointer to help him to find the game. He also trains the dog to fetch the game after it has been shot. (*Courtesy Maine Development Commission*)

success depends upon long practice and careful training. If one is to develop any one of his senses to make it particularly acute, he must begin early and practice patiently. No person is likely to become a good observer unless he begins at an early age *to take an interest in things about him,* and *to practice giving attention to details.*

8. Why do we study science? Most persons who plan a journey or an excursion will look up maps before they start. Few persons are willing to ramble into byways, to blaze new trails, or to explore new territory without definite plans. Sometimes they take both a guide and a compass.

As we begin the study of science, let us make our plans. We may start by looking about us and taking stock of what we find. We shall examine our own fitness and equipment for studying science. We shall learn how to adapt to our own use the things which nature supplies so generously. We shall watch the changes which are constantly taking place about us. We shall find out what methods a scientist uses in his work. We shall learn, too, how men improve upon

the raw materials which nature furnishes them. Then we shall be better fitted to begin our journey and to explore new fields. In our study of science, we must keep in mind seven goals.

a) *To find out what things are and how they work.* When Robinson Crusoe landed on his island, he looked around to see what he could save from the wreck. He made several trips to the ship to bring in supplies for future use. His next step was to explore the island to learn what it would supply for his future needs after his store of food had become used up. Robinson Crusoe, of course, had his own good reasons for finding out all he could about his environment. For different reasons, a child becomes interested in his surroundings. For at least two years after he is born, a child is more or less helpless. Then he begins to take a keen interest in things around him. He asks questions about the things he does not understand. He learns quickly because he keeps all his gateways to knowledge open. In your study of science you should explore and investigate as earnestly as Robinson Crusoe or your three-year-old brother. By asking intelligent questions, you can learn the answers to *Why, How, What is it,* and *How does it work?*

b) *To learn the value of experimenting.* We owe a great deal to the English scientist, Francis Bacon, for showing the importance of experimental methods in finding out the truths of science. Among other things, he wanted to learn how well snow preserves meat. He tried the experiment of stuffing a fowl with snow. It is reported that he caught a fatal cold while stuffing the fowl, and for that reason he was not only a pioneer in scientific methods, but also a martyr to science.

Aristotle (ăr′ĭs·tŏt′l) was one of the greatest of the Greek *philosophers.* He made many mistakes, chiefly because he did not feel that it was necessary to check his beliefs by try-

ing an experiment. For example, he said that a stone weighing ten pounds would fall ten times as fast as a stone which weighs one pound. In this he merely guessed, and he guessed wrong. Galileo (găl'ĭ·lē'ō), an Italian philosopher, did not believe Aristotle's statement, and he decided to test its truth. [See Fig. 10.] He climbed to the top of the Leaning Tower at Pisa, Italy, and dropped objects of varying weights. He found that they all fell to the ground at about the same rate, regardless of their weight.

You can easily duplicate Galileo's experiment and check Aristotle's statement by tying two bricks together and dropping the two bricks and a single brick at the same time from an upstairs window. Be sure, of course, that no one is in the way. Do the single brick and the two tied together reach the ground at the same time?

Edison's success as an inventor depended greatly upon his liking to perform experiments. Someone told him that a certain chemical would not dissolve in any liquid. He did not believe the statement, and spent a whole day trying to dis-

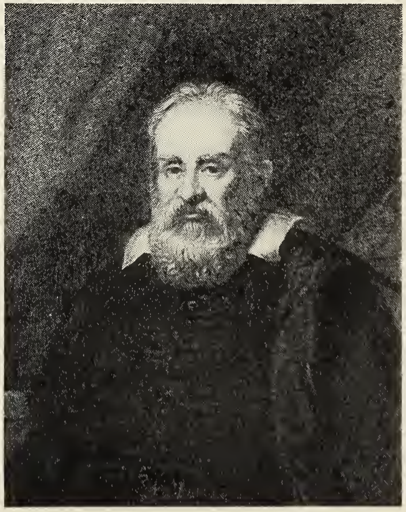


FIG. 10. Galileo was a famous Italian scientist. He worked out the law of falling bodies. Sitting in the cathedral at Pisa, with his finger on his own pulse, Galileo counted the number of times a huge chandelier swung to and fro while he timed the number of swings with his heartbeats. Then he worked out a method of using a swinging pendulum as a timekeeper.

solve the chemical. At last he found two liquids, either one of which would dissolve it. When he was working on the *incandescent* lamp, he sent men long distances over the world to find some material which he could use to make a thread, or *filament*, for use in the electric bulb. It had to be something through which electricity could pass. It could not be used if it melted or broke. He even tried a hair from the beard of one of his helpers. After a couple of years' search, some of his men brought some bamboo fibers from the Orient. They were used in his first successful lamps.

No one man can hope to live long enough to experiment in all fields of science. Therefore one scientist must depend to a great extent upon what others have done. When several careful observers get the same results from separate experiments, the facts they have proved are added to the truths already known in the vast fields of knowledge, and they become scientific laws.

c) *To explore some field of science for ourselves.* Some persons like to study the stars and the planets. Their interest is in astronomy. They spend hours searching the heavens, either with the use of the naked eye or with the aid of a telescope. They are very happy if they discover a new star, a new comet, or a new planet.

Some persons are fascinated by the study of animal life. Louis Agassiz (ăg′*ȧ*·sē) is said to have known more about fishes than any other man knew. Luther Burbank was known as the "plant wizard." He spent hours and hours in studying plant life. He produced hundreds of varieties of poppies; he grew white blackberries; he produced thin-shelled nuts; he grew spineless cacti (kăk′tī, plural of *cactus*). [See Fig. 11.]

Some of you enjoy experimenting with your chemical or biological sets. Others may be interested in electrical toys

FIG. 11. Luther Burbank, famous horticulturist, founded and operated experimental gardens in Santa Rosa, California, where he improved many different fruits, flowers, and vegetables. When Burbank experimented with a plant, he almost always succeeded in producing a better one. The Burbank potato is a big improvement over others. The plumcot, which he originated by crossing the plum and the apricot, is a most unusual fruit. (*Ewing Galloway*)

and appliances. Some of you like to collect flowers, rocks, or insects. In your excursions into the fields of science, you need to explore a broad field and to learn something of several sciences. One of them may so fascinate you that you will wish to make it your hobby or to pursue it as a life work. As you experiment, you must check your results to see whether they are right.

d) *To study ourselves and our environment.* "Know thyself" was the motto of the famous Greek philosopher Socrates (sŏk′rȧ·tēz). In studying science, we shall make this motto include our environment as well as ourselves. To live safely and successfully, we should know how to make the best use of our environment. For example, we need to learn which of the foods that nature produces are nourishing; we need to learn how to avoid poisonous substances. Each leaf of the Virginia creeper usually has *five leaflets.* The creeper is harmless, but the poison ivy, which has *three leaflets*, is

Fig. 12. Every boy and girl who goes hiking should be able to recognize and avoid poison ivy. It can be recognized by its *three* leaflets. Virginia creeper, or woodbine, somewhat resembles poison ivy, but it has *five* leaflets; it is harmless.

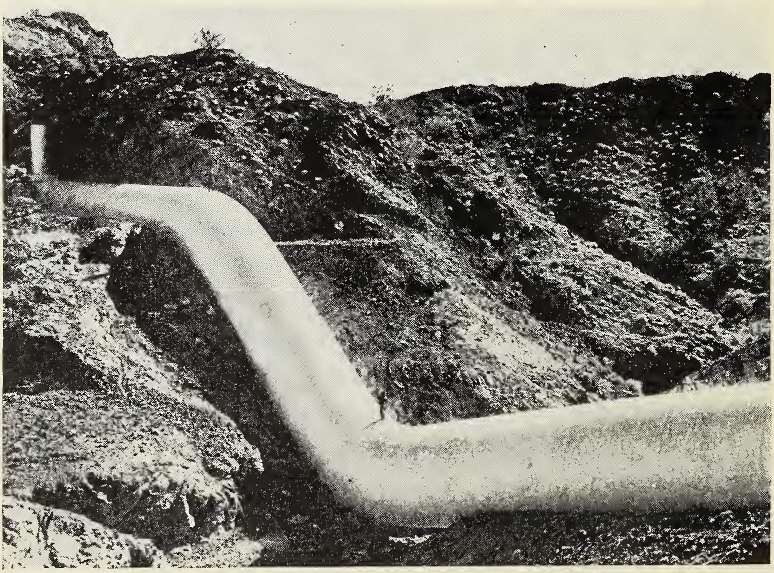


Fig. 13. This aqueduct, which is 16 feet in diameter, carries water 392 miles from the Colorado River to Los Angeles. Notice how small the man standing at the lower bend appears. (*Photo by Metropolitan Water District*)

harmful; it must be avoided. [See Fig. 12.] We need to learn also that some water is unfit to drink, and that some water is perfectly safe. The appearance of the water is not a safe guide. We shall want to learn why cities must spend thousands of dollars to secure for their inhabitants an abundant supply of clean, wholesome water. [See Fig. 13.]

We know that fresh air is necessary for health, and we can learn how to secure an abundant supply for our dwellings. By the use of sanitary methods, communities install garbage-disposal plants and sewage systems to get rid of harmful wastes. Thanks to the experimental work begun by that great Frenchman, Louis Pasteur, we now know what germs cause a great number of diseases. Doctors have learned how to kill many such germs, either outside or inside our bodies. Modern medical methods have added at least ten years to the life of the average American citizen. [See Fig. 14.]

e) *To learn how man improves his surroundings.* Primitive man lived in caves to protect himself from storms, from severe cold, and to some extent from wild beasts. Man's mastery over the wild animals is due to the fact that he learned

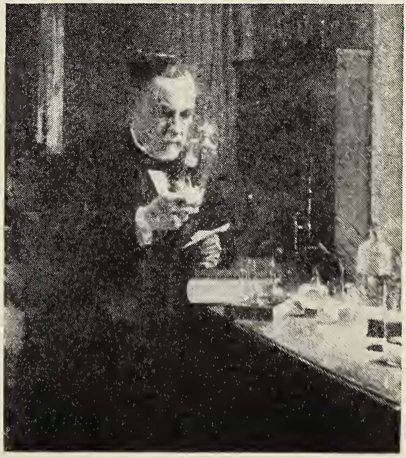


FIG. 14. Louis Pasteur was one of the greatest scientists. If he had not lived, one out of eight of us might have died in infancy from diphtheria. He was the first to show why foods spoil and to prove that bacteria may cause disease. We call the process of heating milk to kill germs *pasteurization,* in honor of Pasteur, who discovered it. Such men as Pasteur gave to the world the knowledge which has made possible modern medical methods.

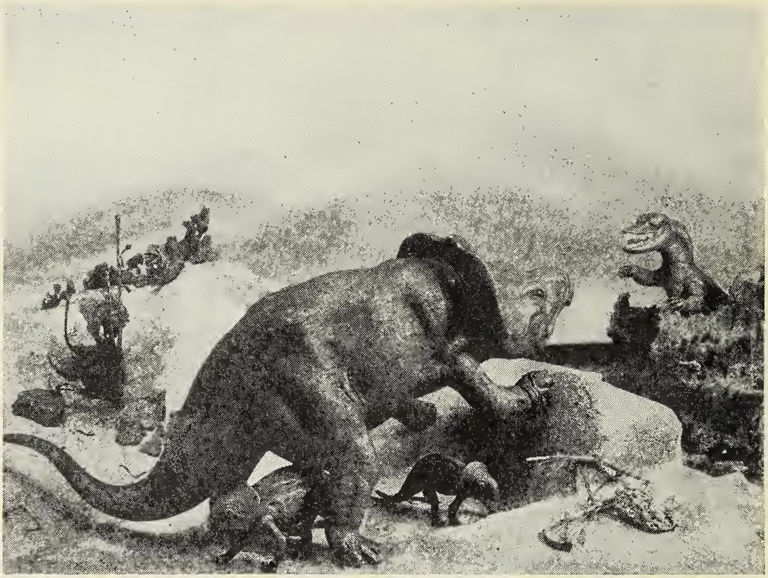


FIG. 15. Are you not thankful you did not live in the Stone Age with such monsters? (*Courtesy Sinclair Refining Co., Inc.*)

how to make tools and weapons. Imagine meeting a monster like that of Figure 15 or Figure 16 if you had no weapon! What would you do to protect yourself?

In the story of the progress of man we are thrilled by his more or less successful efforts to conquer nature and make it serve him. We now live in comfortable homes. We use tools to make our work easier. We spin and weave plant and animal fibers for our clothing. We use the steamboat, the locomotive, the automobile, and the airplane for rapid transportation. We bring fruits and other foodstuffs from distant lands. We use the telephone, the telegraph, or the radio for quick communication with our neighbors. Man's success in controlling the forces of nature and in improving his surroundings shows the triumph of his mind over the hardships in his environment.

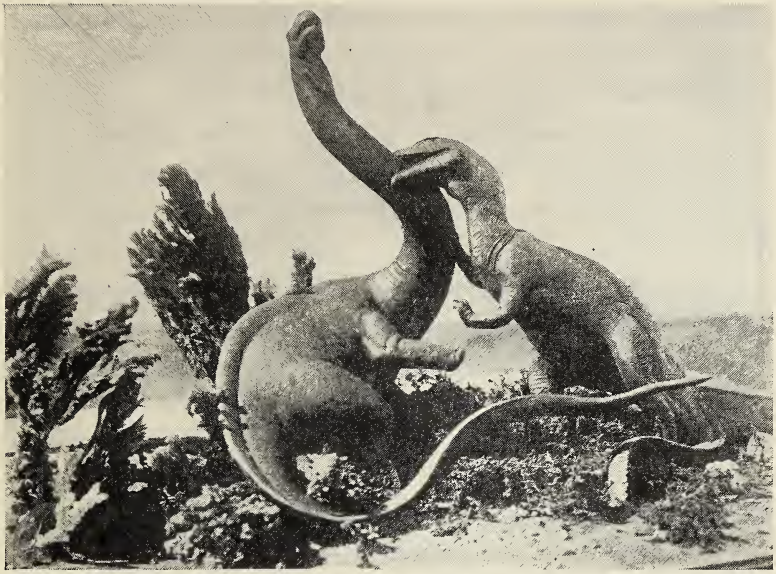


Fig. 16. No doubt many of the creatures of the Age of Reptiles killed off one another. (*Courtesy Sinclair Refining Co., Inc.*)

f) *To show that there is a cause for every effect.* Have you any *superstitions?* Would you sit down to a dinner table set for thirteen persons? A real scientist would not hesitate, because he does not believe in " bad luck." He is sure that there is a real cause for every effect. It is difficult to understand how an American can be superstitious about the number thirteen. There were thirteen original colonies. Our flag has thirteen stripes. Admiral Perry had thirteen ships in his naval fleet when he won the Battle of Lake Erie, and that battle was fought on the thirteenth day of the month.

Columbus should have ended the superstition about Friday when he set sail from Spain on a Friday. Ten weeks later he landed on the island of San Salvador, again on a Friday. Are we thoughtful Americans if we say that Friday is an " unlucky " day?

You are familiar with the superstitions about the black cat, the spilled salt, walking under a ladder, the broken mirror, and many others. Is there any real reason why a black cat can cause you misfortune merely by crossing your path? You might possibly have something dropped on your head as you walked under a ladder, but there would be no magic about that.

Is there any sense in thinking that a four-leaved clover, a horseshoe, a " lucky " penny, or a rabbit's foot can charm away evil spirits? Did you ever think how silly it looks to see a person " knock wood " when he tells someone that he has not had a cold for several months?

How did such nonsense begin? Some persons think that the Friday superstition arose from an old custom followed in some countries of hanging criminals on Friday. In such manner some persons try to explain the origin of superstitions. A few years ago Dr. J. O. Frank, of the Wisconsin State Teachers College, asked his students to make a report of the various things about which some ignorant persons are superstitious even in our day. They found eighteen hundred different things about which some persons living in the Fox River Valley in Wisconsin are superstitious. A survey made in Germany a number of years ago showed a list of some seven thousand superstitions.

Superstitions are not simply idle fancies. They are beliefs which may produce harmful results. They breed fear in persons. Such fears destroy happiness. They cause some persons to spend thousands of dollars every year for worthless " charms," or for readings from cards or tea leaves. Thousands of dollars are spent annually for astrology. Some beliefs are allied to various forms of sorcery. Belief in them may result in putting off a proper treatment of illness until it is too late.

Your study of science should convince you that things do not "just happen." There is always a cause for everything, although we may not always be able to find or to explain it. You may be certain that there is no magic in a four-leaved clover to protect you or to give you good luck.

g) *To form scientific habits of thinking.* A boy was planting potatoes. A neighbor boy said that his father had told him that potatoes should always be planted at the "dark of the moon" – when there is little or no moonlight. He said that ground moles would eat the potatoes if they were planted in the "light of the moon" – when the moon is full or nearly full.

The first boy had been studying science in school and had formed some scientific habits of thinking. He had learned to doubt statements which seem unreasonable. He knew that moles live underground and that they do not see very well. He did not believe that moles could see underground, even if the moon were shining brightly. He guessed that moles find their food by using the sense of touch and smell. [See Fig. 17.] Then, like a true scientist, he decided to try some experiments to find out whether the moon's phases make any difference in the growth of plants.

He planted a few rows of potatoes at full moon and an equal number of rows at new moon. In some rows he used

FIG. 17. Moles are tireless diggers. They burrow rapidly into the earth with their long claws, sometimes tunneling as far as 300 feet in one night. (*Courtesy United States Department of the Interior*)

commercial fertilizers, and in other rows he used no fertilizer. He watered some rows from time to time, but he permitted other rows to depend upon rainfall. Some rows he left uncultivated, but others he cultivated by stirring the soil occasionally. From his experiments he learned: that the ground moles did not bother his potatoes any more when planted at full moon than they did when planted at new moon; that potatoes grow larger crops when the ground is fertilized; that potatoes need plenty of water; and that the ground should be stirred frequently to let the air get into the ground.

When you hear a new statement or see something which you do not understand, what do you do? Do you accept what you hear or see, without question, or do you follow the *scientific method of thinking?*

a) Try to define the problem and make it clear.

b) Think about the facts and try to give a reasonable explanation.

c) Question all statements and explanations until you have studied them.

d) If possible, experiment to prove whether the statement or explanation is true.

e) Make sure that your observations are accurate.

f) Be careful not to let your new ideas or your own wishes influence your observations.

g) If you find that the results of your experiments do not agree with your opinions, change your opinions to fit the facts.

h) When you arrive at the truth, try to classify your findings into general statements, or even into laws.

A scientist must observe accurately, experiment carefully, forget personal opinions, consider his facts thoughtfully, and then draw conclusions. He tries out his conclusions, too. Thus he forms *scientific habits of thinking.*

9. What has science done since Washington lived? Suppose it were possible for George Washington to come back to our world. Suppose that he came to your house as a week-end guest. You are to be his guide. Your father gets out the family car and drives you to the railroad station. Our first President never saw an automobile. It is your duty to show him the engine and to explain what makes it go. For the first time he would have the pleasure of riding on rubber tires. Possibly you are taking him to New York by way of a Pennsylvania Railroad train in order to show him how much the city has changed since the days of the Revolutionary War. Washington was brave, but do you not imagine that he would be a little frightened when the locomotive roared into your station? Try to imagine the expression on his face when you told him that the train was passing under the Hudson River, and that there are two tunnels under that river through which automobiles may be driven.

You might take him uptown on a subway train and let him walk across the bridge that bears his name. [See Fig. 18.]

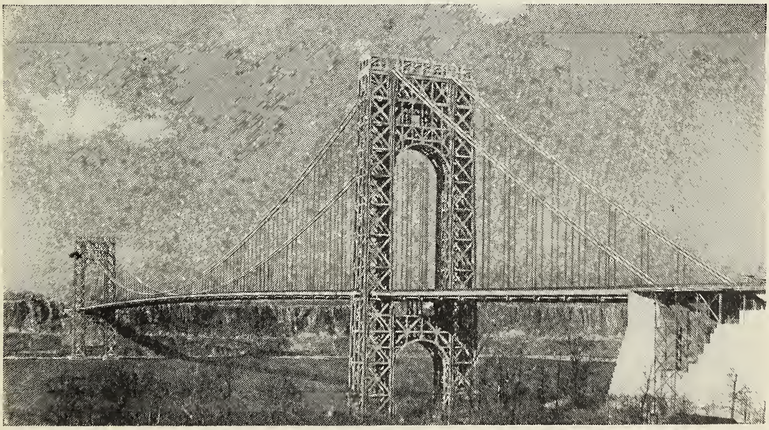


FIG. 18. The George Washington Bridge spans the Hudson River. It is 8700 feet in length, and the steel cables which support the Bridge are 3 feet in diameter. (*Courtesy The Port of New York Authority*)

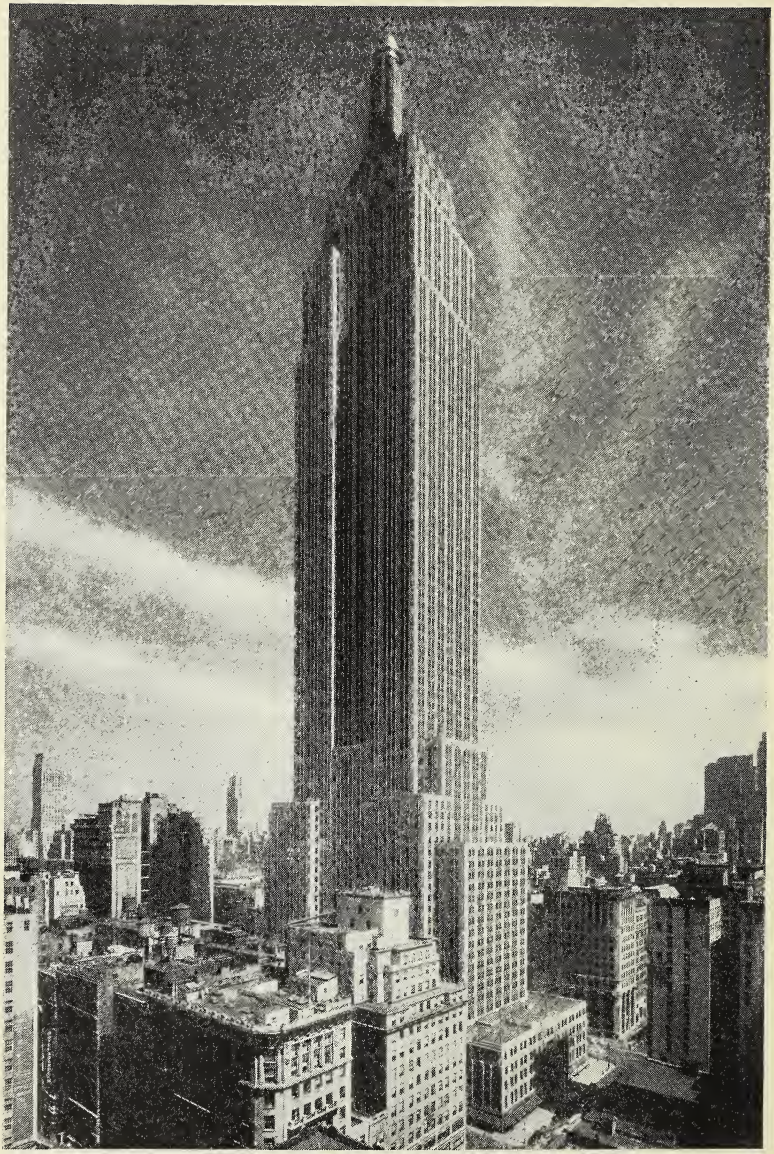


FIG. 19. The Empire State Building is the tallest man-made structure in the world. It towers almost a quarter of a mile above the pavement. There are enough offices in it to house all the workers of a small city. (*Courtesy Empire State Building Corp.*)

Then you could take your visitor up in an elevator to the tower of the Empire State Building, if you could persuade him that it is safe to ride on elevators. [See Fig. 19.] From the top of the building, almost a quarter of a mile high, he could get a bird's-eye view of the great city and look away to the New Jersey plains and mountains. He could even see Morristown, where he spent such a cruel winter with his army. To give him a better view of New York's skyline, you could take him for a ferryboat ride. [See Fig. 20.]

In all cases you would need to do a great deal of explaining, for you would need to remember that George Washington never saw a steamboat, a steam engine, an electric train, an elevator, an automobile, or an airplane.

In the evening you could entertain him by the use of a phonograph, an electric player piano, or the radio. You could explain to him how to use the telephone, and permit

Fig. 20. Do you recognize any of the buildings in the New York skyline? This view was photographed from a boat in the East River, which is one of the waterways that make the city an island. (*Courtesy American Airlines*)

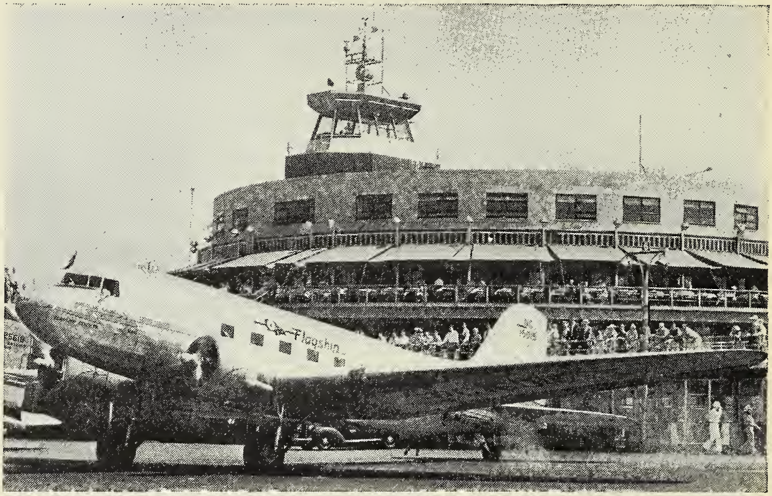


FIG. 21. This huge airplane is about to take off from La Guardia Field, New York City's new airport. The persons in the background pay ten cents each to come and watch the airplanes take off and land. (*Courtesy American Airlines*)

him to talk to the President of the United States at his home in the White House in Washington. He might like to send a telegram to Boston or a cablegram to England. Perhaps he would enjoy a talk with the King of England by trans-Atlantic telephone.

The following day you might persuade him to go to La Guardia Airport to fly to Chicago. [See Fig. 21.] That mid-western city was not founded until more than thirty years after Washington died. You could get back home in time to spend the evening at a motion-picture theater.

In the country, too, surprises would await him at every turn. It might be a powerful gasoline engine pumping water for the livestock on the farm. Possibly the same gas engine would be used to make electricity for lighting the farm home. Instead of the old sickle or the cradle for reaping wheat or

oats, he would find a self-binder drawn by a farm tractor.

Numerous chapters could be written telling of the many improvements which are so familiar to us that we are likely to forget that they were unheard of or even unthought of when Washington rode from New York to Philadelphia or when he crossed the Delaware. These inventions and devices have come to us as a result of the scientific method of solving problems.

QUESTIONS

1. Compare the parts of the flower of an apple tree with those of a pear tree. Do you find any likenesses? Compare the outside and the inside appearances of the fruits of the two trees. Do you think the apple and the pear are so much alike that a botanist would group them in the same family? Give reasons for your answers.

2. Compare a peach and a plum in the same way that is suggested in question 1. How are they alike? Does a cherry seem to be related to either the peach or the plum?

3. An astrologer may tell you that you were born under a lucky star. You will probably pay at least a quarter for the information. If we exclude our sun, the nearest star is more than twenty million-million miles from the earth. Do you think that so distant a star could influence your life? After thinking over this question, would you sell, for a quarter, the so-called information which the astrologer gave you?

4. Try to find out what farmers mean when they speak of a "wet" moon. What do you think of such an idea?

5. What sense would a manufacturer of perfumes train carefully?

6. Why must an artist be a good observer?

7. Where do you look for the full moon at about six o'clock in the evening?

8. In what direction do you look to see the new moon at sunset?

9. Name at least six important things that have come as the result of experiments.

10. Tell the names of at least three men who were interested in some great invention.

11. Why do many watches have no figure on the dial at the six o'clock position?

12. Did you ever see a squirrel climb down a tree headfirst? If so, explain how he does it.

13. Can a cat climb down a tree headfirst? Give a reason for your answer.

14. Give at least five examples with which you are familiar, to show that nature is generous or wasteful.

15. The boys in a high-school class can probably tell the score of a football game played with a rival team a year before. How do you explain such remarkable memory?

16. Why does a person with a cold sometimes say that his food does not taste good?

17. If you get seven zeros in succession, does that prove that seven is a lucky number?

18. A boy was happy at finding a horseshoe. He slipped as he stooped to pick it up and punctured his hand on a nail in the shoe. Is that proof that the finding of a horseshoe brings " good luck "?

19. Make a list of some of the habits you would expect a scientist to have.

20. Did you ever pay a gypsy to tell your fortune? Do you feel foolish when you pay to have someone read your future from your palm or from the leaves in your teacup?

21. See if you can find a quarter with thirteen stars on one side. If you do, would you consider it bad luck to use such a quarter?

Plants Are Interesting Neighbors

CAN you imagine what your town would be like if there were no living things in it? Can you imagine the whole world without life? It would be a strange and lonely place. Perhaps some of you have been on a desert or in a rocky, barren region. Were you glad to get away from such a dry and lonely region into places where there were grass, and flowers, and trees, and where you could see cows, dogs, horses, birds, and human beings like yourself? Living things are so important that it almost seems as though all the substances of the earth had been formed for their benefit.

Scientists are sure that the earth itself existed many millions of years before life appeared here. Gradually through the ages conditions changed. The once-hot earth cooled off. Clouds of vapor, miles thick, condensed to form water and became rivers, lakes, and oceans. Atmosphere was formed.

No one knows how life started on this earth. But most persons agree that it must have appeared in very simple

forms. We do not know whether this primitive life was like plant life or animal life. Nor does it matter. We do know that *something living* was created from a dozen or more chemical elements, and that this *something* was entirely different from the form of the lifeless rocks, water, and air. Here was the first miracle of biology that began the " tree of life." From this beginning the " tree of life " grew and branched into more and different living creatures, both plants and animals. Millions of these forms lived and died. But millions of descendants have lived on.

Think about these!

1. Can you name all the trees you pass in coming to school?
2. How many kinds of weeds are growing in your garden or in the garden nearest your home?
3. Do you know a plant that grows best in water? One that grows well even in dry soil?
4. What is your state flower?

Words for this chapter

Specimen. An individual.

Immune. Not subject to; free from.

Conservation (kŏn′sẽr·vā′shŭn). Preserving and keeping alive under natural conditions.

Bacterium (băk·tḙr′ĭ·*ŭ*m), *plural,* **Bacteria.** A single cell of certain one-celled flowerless plants that tend to cause decay.

Crown. The upper leafy part of a tree.

Typical. Representing the average of a group of things or individuals.

Texture. Hardness or softness of a tissue or part.

Crossing. Mating two possible parents with the purpose of producing offspring.

Sport. A new kind of plant or animal which comes into existence in nature and which is not like its parents.

CHAPTER 1 ________________ UNIT 1

What Plants Grow Near Your Home?

10. How can we get acquainted with plants? If a new family moves into your neighborhood, or your family moves into another neighborhood, very soon you and your neighbors will be speaking to each other. Before long you will know many things about the other family: where they came from, how many there are in the family, whether the children are boys or girls, what their names are, whether they have a dog, a bicycle, or other possessions – in short, what kind of people they are. This is getting acquainted. Afterward you can be neighborly.

In getting acquainted with plants, you will of course have to take the first steps. The plant cannot come to you; therefore you will have to visit the plant where it is growing. It is true that many *specimens* of leaves, flowers, or fruits or even entire plants may be brought into your classroom or into your home. If you put living plants or flowers into water

in a vase or a bottle, they will stay fresh for several days. You can examine them and compare them with pictures and descriptions in books. You can even learn their names. This is good as far as it goes. But you can never really become acquainted with plants until you know what they are like in the places where they commonly grow.

11. How many weeds do you know? If you are a country boy or girl, you probably already know many plants. If you have ever helped weed a garden, you have many times pulled up chickweed, sorrel, purslane, lamb's quarters, bindweed, mustard, and the like. And you know, too, what hard work it is to grub out dock and pigweed with their long taproots, and the quack grass with its stemlike roots and their never-ending branches. If you live in a city, there will still be many chances to learn about some of the weeds. City gardens are not *immune* to weed visitors. And in almost every vacant lot there are weeds such as ragweed, various kinds of wild

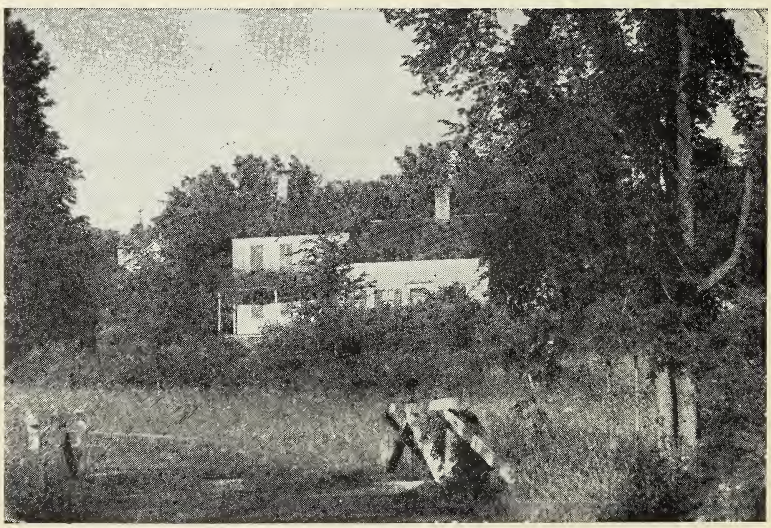
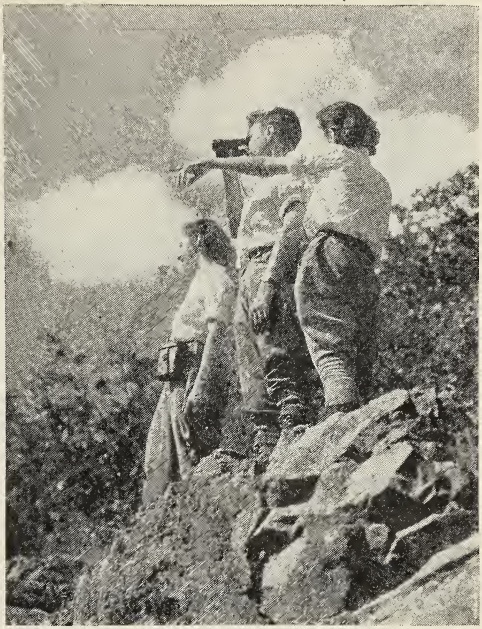


FIG. 1–1. In vacant lots, in unkept yards, and along country lanes you can find a wide variety of weeds to study. (*Philip D. Gendreau*)

Fig. 1–2. Boys and girls who live in the city or in the country have good opportunities to observe wild plants where they naturally grow. If you live near a region such as the Palisades State Park, on the Hudson River, you are especially fortunate, for you will be able to visit plants which grow in unusual places. (*Miller* from F. P. G.)



grasses, dandelions, and thistles. Sometimes, in unimproved city property, you will find beautiful flowering weeds, such as yellow clover, daisy, white sweet clover, Queen Anne's Lace, St.-John's-wort, butter-and-eggs, goldenrod, and many more. In the country these wild plants are common in the fields and along the roads and lanes. [See Fig. 1–1.]

12. Can you find wild plants growing in the country? You do not have to grow plants in order to become acquainted with them, but you must be able to observe them, and, if possible, to see them where they are growing naturally. Then you will learn what sorts of places they like and what kinds of plant and animal companions they have.

Most city boys and girls enjoy hikes into the country, and many are fortunate enough to be able to spend their summer vacations in camps or on farms where they have a good opportunity to observe wild plants. [See Fig. 1–2.]

Perhaps your counselor in camp or your teacher in school will help you to start a collection of pressed tree leaves or of pressed wild flowers. This is an excellent way to become acquainted with the trees and the wild flowers. If you gather the specimens yourself, you are bound to see trees and plants " at home." You should always remember to be careful, when taking off a leaf or a flower, not to injure needlessly the rest of the plant.

13. Why must some plants be protected? Many wild flowering plants are becoming so rare that *conservation* laws have been passed in more than twenty states in the United States, to protect certain of their wild flowers. For instance, in Massachusetts you are liable to be fined as much as a hundred dollars for picking trailing arbutus, the state flower. In New Jersey you must not gather any wild plant without the consent of the owner of the land. New York State laws forbid the gathering of eight different wild flowers: three kinds of moccasin flowers (lady's-slipper orchids, for example), fringed and closed gentians, dogwood, trailing arbutus, and mountain laurel. The state of Colorado will not permit the picking of columbine, the state flower. Oregon protects plants native to that state, and North Carolina conserves wild plants and flowers along the highways of the state.

However, there are many, many wild flowers which grow in abundance. You may obtain a collection of several hundred kinds, all of them fairly common, without breaking any law. [See Fig. 1–3.]

14. What plants are your neighbors? Even if you rarely go into the country, you can learn about living plants. Begin with the weeds in your own garden or the plants in a vacant lot near by. Why not start a collection of tree leaves from the trees on your block or in your section of your village?

FIG. 1–3. Do you recognize the flowers in this picture? They are rhododendrons, the state flower of West Virginia and Washington. (*Ewing Galloway*)

But do more than collect a leaf from each tree. Look carefully at the tree from different sides. See whether the bark is rough or smooth. Note the color of the old trunk and of the younger branches. Most of our trees shed their leaves in the fall, but some are evergreens. Remember to which group each tree belongs. A tree is our friend. It gives us welcome shade and provides shelter for our allies, the birds. Civilization owes a great deal to trees for wood and other valuable products. Forests are valuable in helping to regulate the water supply and to prevent floods. Keep these facts in mind when you are studying trees. Appreciation of trees will help you to remember their names and to be interested in all parts of your study of trees.

There are many tree books and flower guides, illustrated with colored pictures and provided with descriptions, which you can get from libraries. These books will be of great assistance to you as your collections increase and as you learn more about plants.

15. What is the color of most plants? If you were asked to tell exactly what a plant is, what would you say? Let us start with color. What is the color of most plants? Can you think of a plant which is not mostly green? It is true that flowers are brightly colored and are rarely green. And the bark and twigs are brown. Many fruits are yellow, red, or blue. But you would be correct in stating that the general color of plants is green.

16. Do most plants have leaves? What other thing is true of plants? You can answer this question by examining several plants. What part of the plant is the greenest? Is it not the part we call the *leaves?* There are a few kinds of leaves that are not green. Almost everyone must have seen the copper beech, a tree whose leaves are a deep red. The leaves of some begonias are white, green, and red. Such plants are exceptions to the rule, which is that leaves are green. It is also true that most plants do possess leaves. Have you ever seen a plant that did not have leaves? There are many such plants. Examples would include a mushroom (maybe you call this plant a toadstool), a barrel cactus, and the mold that sometimes grows on stale bread. Even though no one of these three has any leaves, each is as truly a plant as is grass or a pine tree or the geranium in your house. [See Fig. 1–4.]

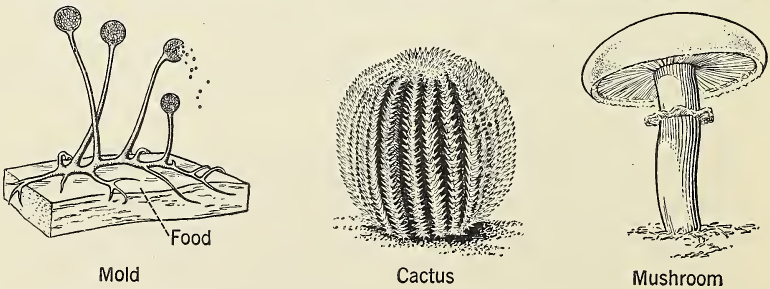


FIG. 1–4. Three examples of plants which never bear leaves.

17. Do most plants have roots? Pull up a weed or a clump of grass. What part of the plant was out of sight below the ground? This part is called the *root*. Sometimes there is only one, big, thick root, as in the carrot, beet, or burdock. But there is rarely only one root. Grass has a great many fibrous roots – small, hairlike roots. When the dirt is washed off, the roots appear white or brownish. As a rule, all the common plants have roots. The roots hold the plant firmly in the ground and absorb water from the soil.

18. Do most plants have stems? Look at the weed again and see what connects the roots and the leaves. This part is called the *stem*. In a tree this becomes the trunk. Most stems have branches. This stem or trunk supports all the plant or tree above it and is the part through which liquids are carried up to the leaves from the roots, or down from the leaves to the roots.

19. Do most plants have flowers? Can you think of any other thing that applies to plants? What is the most beautiful part of some plants – the colored, showy part? If you are thinking *flowers*, that is the right answer. If we start to name several plants that bear flowers, we may think first of the rose, the apple tree, the trailing arbutus, the dahlia, corn, and many, many more. In fact, it would be much harder to think of a plant which at some time of the year does not bear flowers. Do you know that maple trees and even evergreen trees bear flowers? Have you ever seen the yellow flowers of witch-hazel shrubs, blossoming in the late fall, sometimes when snow is on the ground? Did you know that even grass bears flowers? Many plants, however, never have flowers; four examples are ferns, mosses, mushrooms, and mold.

20. Do most plants bear fruits? Do you know what develops on most flowering plants after the flower dies? It is the *fruit*. Can you name some fruits? Of course, oranges,

apples, lemons, and bananas, which you see rather frequently, are fruits. But nuts, squashes, coconuts, beans, and many other products are also fruits. Since the fruit grows only on plants which have had flowers, you should be able to name several plants which never can bear fruits. [See Fig. 1–5.]

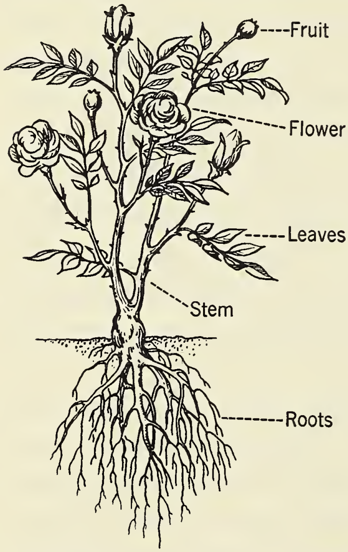


FIG. 1–5. A green plant usually has roots, one or more stems, leaves, and, in season, flowers and fruits. The rose is a good example of a green plant. Have you ever seen the fruit of the rose plant? Try to find an example, and bring it in to the classroom for others to see. Be sure to ask permission of the owner before you carefully remove the fruit from the plant.

Plants, then, are living things that are mostly green in color; they usually have roots, one or more stems, and leaves; and they usually bear flowers and fruits.

21. Do plants differ in size? Even though most plants are alike in many ways, there are great differences in size, shape, texture, and many other things. Think for a moment of the largest tree you know. Even though it is a towering pine, or a huge oak, or a spreading willow, yet there are trees near the western coast of the United States, called *redwoods*, or *Sequoia* (sē·kwoi′ȧ), which are still taller. In fact, the tops of such mammoth trees may rise to a height of over 300 feet. [See Fig. 1–6.]

What is the smallest plant you ever saw? Something much smaller than a dandelion? Those of you who weed gardens will recall chickweed, a tiny plant growing by the sides of walls and among the garden plants. In some quiet pools of water you can find green patches. When you examine them closely, you see that they consist of hundreds of little plants, called duckweed. Mold is a plant that is even smaller. There are some plants, such as *bacteria,* so small that one cannot see them without a microscope. The redwood, which is the largest of all living things, may be a trillion times the size of a single *bacterium.* This shows what differences in size there are among living plants. Yet when the enormous redwood tree started its life, it was not much bigger than a bacterium. The strange part of that story is that the bacterium remains so small, while the living spot destined to be a redwood tree has in it the strange ability to become one of nature's marvels in size.

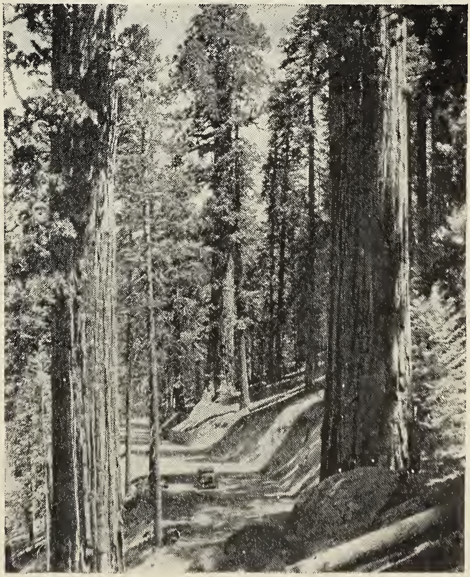


FIG. 1–6. Compare the size of the car with the size of these huge redwood, or Sequoia, trees, which are growing in Sequoia National Park. They are often called sentinels. Do you know why this name is especially appropriate for them? Some redwoods are known to be over two thousand years old. These trees were mature plants when the pyramids were being built in Egypt. (*Courtesy Sequoia National Park*)

22. **Are you acquainted with some vines?** Travelers tell of strange plants seen in the jungles of the tropics. These plants look like huge snakes coiling and twisting through the trees. Actually they are only vines. There are many kinds of vines. Undoubtedly some vines, such as ivy, are growing near you, even though you may live in a city. A wild vine that you should be able to recognize is poison ivy, mentioned in Chapter 1 and shown in Figure 12. This plant has three bright green leaflets on one stem. In the fall of the year it bears gray berries. *Avoid touching this plant* because it may prove to be very poisonous to you. Woodbine, a harmless and decorative vine, is sometimes mistaken for poison ivy. However, it usually has five leaflets, whereas poison ivy has three. Blackberry bushes send out long branches which become tangled vines. Can you name other vines?

23. **What shapes do trees have?** We are accustomed to seeing trees like the maple and the oak, which have many branches. At a distance such a tree has a large, rounded appearance. The white pine and the Lombardy poplar grow quite differently from the maple and the oak. Each of these trees looks more like the spire of a church, because it towers high in the air and the top is pointed. Willow trees, especially the kind called *weeping willow*, are likely to have a drooping appearance, since the ends of the branches hang down, sometimes to the ground. The American elm, with its great height and girth, and its huge *crown* of large branches whose ends droop like the weeping willow, is loved by all who live in the countryside around such trees. In some villages, double rows of elms make a leafy series of arches for the roadway, like the aisle in a cathedral. Many regard the elm as the *typical* American tree. [See Fig. 1–7.] The oak also has spreading branches and is a beautiful tree to see and to know. The pin oak can be recognized by branches which

Fig. 1–7. The soft outlines of the elm make it one of the most graceful of trees. It grows well in many parts of the United States, and because of that and because it is so attractive, the elm is a popular tree in this country. Do you understand why it is called a typical American tree? (*Philip D. Gendreau*)

slant downward from the trunk. The *saman* (sä′män) tree of the West Indies has great branches that extend for a hundred feet or more from the main trunk, horizontally. Orchids, air plants, and even shrubs and small trees grow along the upper surfaces of these branches. [See Fig. 1–8.] In warm countries one sees the curious palm trees, most species of which have long leaves like huge feathers bunched at the top of a smooth, unbranched trunk.

24. How much water do plants like? Most plants require at least a moderate amount of water in order to live. The weeds that grow by the roadside and in the garden, the grass in the meadows, and the wild shrubs and trees are not cared for by anyone or watered from time to time, as are your house plants or your lawn or your vegetable garden. Plants that are not thus cared for must depend upon the rains, which may be frequent, but on the other hand may be

FIG. 1–8. The saman tree is known as the rain tree in the West Indies, where it grows. (*Paul B. Mann*)

so infrequent that there will be a dry season called a *drought.* Yet weeds, grass, trees, and other wild plants usually endure even a drought. How do they do it?

a) In the first place, plants send roots down deep into the soil. A wheat plant may send roots down five feet into the soil. That is longer than the plant is tall. You realize how deep the roots are if you start to pull up a weed or a wild shrub. It is very difficult to pull up a clump of grass unless it has first been loosened by a spade or trowel. Most of these plants, in addition, have very long branches in their root system, extending out far from the plant into the soil. The roots of some trees may be four times as long as the average classroom in school. Thus these plants are prepared to get what water there may be in the soil around them.

b) In the second place, there is usually enough change of temperature between day and night to form drops of water on the ground and on the plants. This dew, which we see sometimes in the early morning, adds a little water to the soil.

In very dry regions such as deserts, the plants have developed a thick skin and also spines. These structures take the place of thin leaves, which if exposed to the hot air, would dry almost immediately.

There are certain kinds of plants which will grow only in water itself. Examples of such plants are the water lily, cattail, and pickerel weed.

25. How do plants differ in texture? Plants differ very much in the *texture* of their parts. The familiar asparagus plant has stems that grow so fast that they have not time to become hard. Their softness is one reason why many persons like them for food. Tropical fruits like the mango and the custard apple become very soft when they are ripe, and have a delicious flavor. Many nuts, on the other hand, become hard when they ripen. One such fruit is so hard that it has

been called *vegetable ivory,* and men make buttons from it. Wood such as the linden wood (basswood) or balsa wood is quite soft. Ebony, mahogany, and oak are so hard that they can be worked into furniture only by special tools. Yet the bark of an oak which grows abundantly in Spain, and is called the *cork oak,* is so soft and thick that men strip it from the tree and use it for many purposes under the name of *cork.*

26. How many kinds of plants are there? There are so many kinds of plants that only a few can be noted here. Botanists, the scientists who study about plants, have already named over 300,000 kinds of plants. Yet there may be thousands more to be discovered. You may at some future time discover and name a new plant.

27. Can man develop new kinds of plants? Men have been able to produce new kinds of plants by two methods.

a) *Hybrids.* By *crossing* two related parent plants, men frequently produce a new kind of plant with some characteristics of the parents and some new characteristics. This is called a *hybrid.* For instance, the plum and the apricot were crossed by Burbank. He obtained an entirely different tree, which produced a flower never seen before and bore a new fruit which was called the *plumcot.* The *shasta* daisy was produced in the same way from English, Japanese, and American daisies. New roses, dahlias, sweet peas, and other flowering plants are developed every year in the gardens of florists and seed companies.

b) *Sports.* Sometimes an entirely new kind of plant will come into existence in nature without the aid of man. Such a plant is the well-known ostrich fern, which came from a Boston fern growing in the greenhouses of Mr. Pierson, in Tarrytown, New York. Such plants are called *sports.* Probably many kinds of sports have arisen in nature in the past. Maybe they are occurring now in remote parts of the world.

QUESTIONS

1. What kinds of plants are you best acquainted with? What kinds of house plants have you grown or taken care of? Which ones grew best for you?
2. What plants have you yourself raised in the garden?
3. What other plants have been grown in the garden that belongs to your family?
4. Can you name any weeds other than those mentioned in this chapter? What are they?
5. Can you name plants, other than those mentioned in this chapter, that have no leaves? What are they?
6. What is the tallest tree in your neighborhood?
7. What is the most common wild flower in your neighborhood?
8. What is the rarest wild flower in your neighborhood?
9. Can you name a conservation law of your state?
10. How do roots differ in appearance from stems?
11. Some plants have practically no roots. Can you name one or two such plants?
12. What is the longest root you have seen?
13. Is it true that trees bear flowers?
14. Can you name two evergreen plants? What are they?
15. Name some flowerless plants not mentioned in this chapter.

SOME THINGS FOR YOU TO DO

1. Make a list of all the weeds that grow in your garden.
2. Start a collection of pressed wild flowers. Place each flower and some of its leaves in a natural position between sheets of newspapers. Put a board over the newspapers, and put a weight like a stone or some books on the board. Change the newspaper next to the flowers after a few days. When dry, the pressed flowers can be mounted.
3. Make a collection of three leaves. Label each kind.
4. Look through the catalogue of a seed company to find new hybrid flowers or fruits.

Think about these!

1. How can you tell whether a tree is more than a year old?
2. Common green grass can accomplish something that no biologist or chemist has yet been able to perform. What is it?
3. Why is oak wood harder than the rind of pea pods?

Words for this chapter

Structure. The parts that make up a physical thing; the way in which something is built up.

Cell. The simplest unit of which plants and animals are composed.

Nucleus (nū′klē·ŭs). The most important part of a cell, frequently ball-like in shape.

Protoplasm (prō′tō·plăz′m). The parts of a cell that show life.

Unit. A common part or a common measure.

Duct. A tube in plants used to carry liquids through the plant.

Cambium. The region in a woody stem where growth takes place.

Chlorophyll (klō′rō·fĭl). Green coloring matter of most plants.

Stoma (stō′mȧ), *plural,* **Stomata** (stō′mȧ·tȧ). One of the many openings in a leaf, usually found in the lower surface.

Carbon dioxide (kär′bŏn dī·ŏk′sīd). A colorless gas, present in the atmosphere. It is a source of food for plants.

Oxygen (ŏk′sĭ·jĕn). The most abundant element in the world. It is found in the air, in water, in rocks, and in other things.

Function (fŭngk′shŭn). Use or action; one of the basic activities of a plant or an animal.

Secrete (sē·krēt′). To make or separate substances within the body structure of a plant or an animal.

Protein (prō′tē·ĭn). A food substance necessary for protoplasm.

Energy. The capacity to do work.

Transpiration. The passing off of water vapor from the leaves of a plant.

Oxidation (ŏk′sĭ·dā′shŭn). The combining of oxygen with some other substance.

Excrete (ĕks·krēt′). To pass off, especially referring to wastes.

Reproduce (rē′prō·dūs′). To have offspring.

CHAPTER 2 ______________ UNIT 1

What Are Plants, and How Do We Know That They Are Alive?

28. How shall we look inside a plant? You have already learned that plants vary greatly in the matter of size, shape, and color, and also differ as to the places where they can live well.

We have been considering the outside of plants. Let us now turn our attention especially to the parts inside plants.

In plants there seems to be no natural opening like the mouth in animals. There are thousands of little openings on the underside of each leaf. And there are other openings in the bark on stems, easily seen in the birch and cherry.

But none of these openings could be enlarged to let us see what plants are like on the inside. So we shall have to enter forcibly by breaking or cutting some part of the plant. It is fortunate that plants do not have feelings of pain or distress when parts are cut. [See Fig. 2–1.]

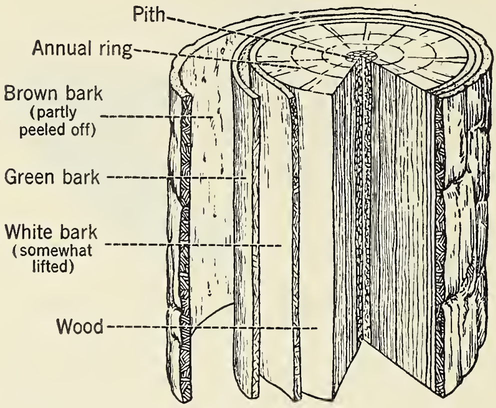


FIG. 2–1. A woody stem has many parts. This diagram shows them separated, so that you can see the relative size and position of each. Every part of the woody stem has some function. Can you tell at least one use to the plant of each part shown here?

29. How do woody stems differ from other stems? Of course you know how different the stem of grass, a common weed, or a cornstalk is from the sturdy stem or trunk of a tree like a pine or an oak. The stems of the grass, the weed, and the cornstalk are easily bent. They are quite soft in comparison with the hard *structure* of the trunk or branch of the tree. The tree is hard because it is largely composed of wood; the other three plants lack such woody structure or have only a little of it.

30. What parts can we find in a woody stem? Let us take a knife and cut off a small branch from a tree. On the outside you find a gray or brownish bark. Carefully peel this away and look for a soft, greenish bark just underneath this. By gently scraping away this green bark, you will find a third layer, the white bark. Peel all the barks away and you come to the wood itself, more or less wet with a sort of sap. Cut across the stem and look at the cut-off end. If it is a young branch, there will be some soft white material in the middle. This is the *pith*. If you look at the outer end of the branch, you will find leaves or merely buds, according to the time of year. Examine a root of this tree, and you will

find about the same parts as are in the stem, with the bark layers somewhat thicker and softer than in the branch.

31. **What parts can we find in a non-woody stem like the cornstalk?** If you similarly examine the stem of the cornstalk, you will find no bark, but a sort of heavy skin, or *rind,* on the outside. Inside this rind is a mass of soft, white pith through which are scattered *fibers,* or hairlike pieces of material resembling the rind. The weed has about the same structure. So have young grass stems. Older grass stems are hollow.

32. **How can we see the cells of a plant?** Thus far you have not discovered any special organs in a plant such as the brain, heart, or lungs of an animal. Nor will you. Yet there is more to be seen. If, by the use of a razor blade, you cut a very thin *section,* or slice, through any part of a plant, and then put this section under the microscope, you will be able to see much more. Let us begin by looking at a tiny piece of the pith. It looks like a great number of soap bubbles. Each of these bubbles, however, is bounded by a definite wall and somewhat resembles a small box, though perhaps pushed out of shape. It is called a *cell.*

33. **What do onion cells look like?** We shall better understand what a cell is if we view through a microscope a piece of a thin skin peeled from an onion. We shall put it on a glass called a *microscope slide,* add one or two drops of water in which some iodine has been dissolved, place over it a cover slip, and then look at it through the microscope. When the microscope is properly focused, you will see a great number of little parts bounded by lines. You will see that these parts are much alike in size and shape. Each part or section is an onion cell. Each cell may seem to have but four sides. [See Fig. 2–2.] It really has as many sides as has a box.

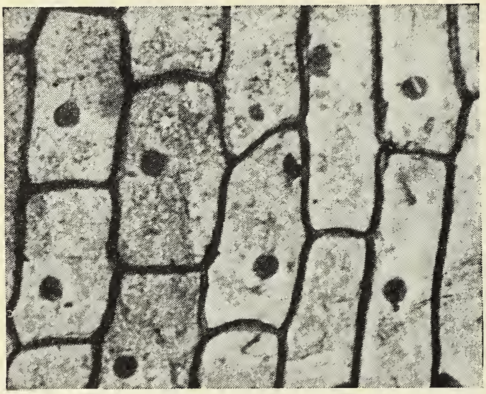


FIG. 2–2. Onion cells are so small that they can be seen only with the aid of a microscope. This enlarged photograph shows that each onion cell is actually shaped like a box. Notice each nucleus. Is it always in the same relative position in each cell? (*Photomicrograph by I. A. Herskowitz*)

34. What are the parts of a cell? Look carefully and you will see, inside each of the cells, a little rounded body, like a tiny ball, which is stained yellow by the iodine. This is the most important part of the cell, the *nucleus*. Between the nucleus and the cell wall, there is generally a liquid. The parts of the cell that are living, such as the nucleus and much of the interior of the cell, are said to consist of *protoplasm*, which is the name the biologist gives to any living substance.

35. Why is the cell considered to be the unit of structure in a plant? If you take a razor blade and make the thinnest possible section through a corn stalk, the stem of a weed or even of a part of the woody trunk of the tree, you find that every one of these plant sections is also composed of cells, somewhat like onion cells. It does not matter whether the sections come from the root, the stem, the leaves, the flower, or the fruit; the microscope reveals the *cellular* structure of the part. Just as a brick wall, when approached, is seen to be made up of a great many single bricks, so plants, from one end to the other, are made up of cells. Thus we see that the cell is the *unit of structure* in a plant.

Look again at the onion cells. Notice how thin the boundary lines or walls of the onion cells are. If the walls of cells

were found to be very thick, such cells might be wood cells. At least all cells of wood do have greatly thickened walls. Wood cells, also, are usually long and narrow. Most cells, if they are not crowded very much, are shaped like boxes, yet cells have many different shapes. The trunk of a tree, because it has enormous numbers of wood cells, is so strong that it can easily support all the many branches above. [See Fig. 2–3.]

FIG. 2–3. A magnified vertical section through a basswood stem. Wood has sliver-shaped cells, and tubes through which water goes up the stem. These tubes may be pitted or they may have spiral bands.

Of course, one cannot see plant cells with the unaided eye. It seems almost like believing a fairy tale to try to realize that a huge tree is *everywhere* composed of tiny parts. These parts are so small that you cannot see them, even when you are holding a piece of bark in your hand.

36. When were plant cells first discovered? If you had been living three hundred years ago, you would not have

been able to see plant cells, even if you had thought that they were there. It was not until 1665 that an Englishman, whose name was Robert Hooke, first saw and described cells. The microscope, with only one simple lens, had only recently been invented. Though the instrument used by Hooke was very crude compared with our microscopes of today, nevertheless it would have been good enough to reveal onion cells if Hooke had chosen to look at a thin section of that plant. [See Fig. 2–4.] However, the cells that Hooke saw were in a thin section of cork.

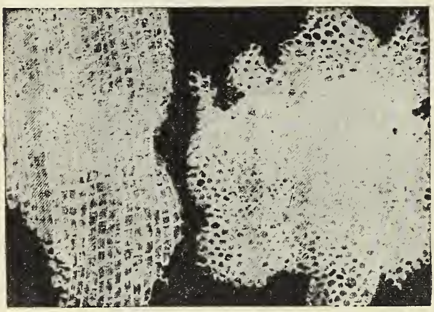


FIG. 2–4. This is the earliest known picture of cells. It appears in the 1780 edition of Robert Hooke's *Micrographia.* Hooke invented the compound microscope, with which he saw cork cells. He was the first man to see cells. (*From "Biology and Its Makers" by W. A. Locy*)

37. What is the cellular structure of a woody stem? You already know the general parts of a woody stem. If you could see the cells of each part under the microscope, you would realize that some of these cells are alike and that others are very different. [See Fig. 2–5.] You have already seen the pith cells in the middle that resemble crowded soap bubbles. In old stems of woody plants, the pith gradually becomes darker and changes to wood cells. It is then called the *heartwood* and is usually considered to be dead tissue. Around this pith, or heartwood, are the living wood cells. If the branch you examined was more than one year old, you will find a ring of tiny cells for each year's growth. In climates where the winter season stops active growth, the cells made at the end of summer are so small that they look like

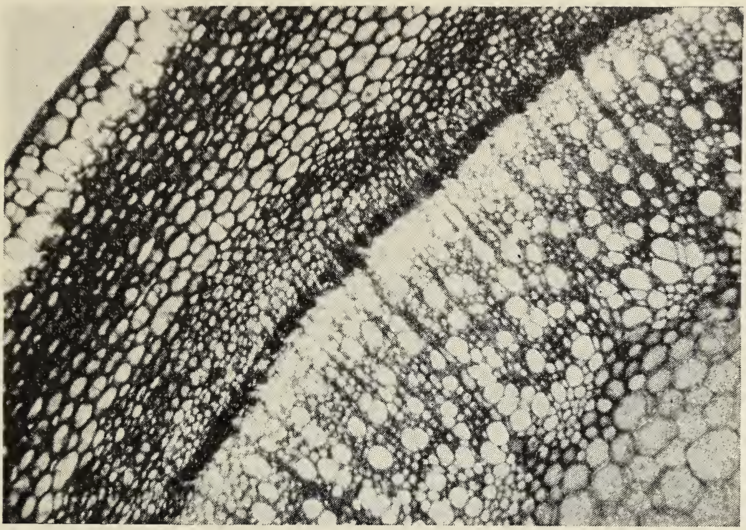


FIG. 2–5. Every part of a plant or animal is made up of cells. This photomicrograph shows a cross section of a young basswood twig. In the lower right corner are pith cells. Next comes a row of wood cells. The openings are ducts through which water comes up. The dark band across the center is made up of tiny cells formed at the end of the growing season. The rest of the cells make up the three layers of bark. (*Photomicrograph by I. A. Herskowitz*)

a ring or a band, in contrast to the larger cells made earlier in the season. The age of old trees can be told accurately by counting the number of such annual rings. Scattered among the heavy-walled, woody cells are tubes called *ducts,* which extend into the twigs, leaves, and flowers. Through these ducts, water is carried up from the roots to all parts of the plant above ground. The outside region of the wood just under the white bark is the region where new growth takes place. This is called the *cambium.* The cells of the cambium are always large. The annual ring, just spoken of, is formed in the fall by small cells, next to which are the large cells of the cambium, formed in the spring. The white bark contains many cells in the form of tubes, like the ducts of

the wood. They are called *sieve tubes.* These sieve tubes carry digested food and other liquids downward from the leaves, to be used by the plant or to be stored in the roots or in the region of the pith.

The cells of the green bark contain a green coloring matter called *chlorophyll.* This same material is found in the leaves in much greater abundance. It is what makes most plants appear green. The cells of the outer bark are frequently flattened out of shape and twisted by pressure and old age.

38. What is the cellular structure of a non-woody stem? In stems like the cornstalk and the bamboo, the thick-walled wood cells are on the outside, making a sort of rind. This is strong enough to support the plant or tree. Scattered through the large pith cells, are long fibers or strands containing tube-shaped cells which are really the ducts and sieve tubes of the plant. In weeds which also lack wood cells, the outside is thick enough to hold the plant erect. [See Fig. 2–6.]

39. What are the cells of a flower like? The cells of which flowers are composed are perhaps the most beautiful

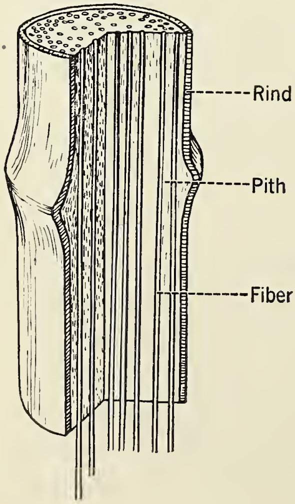


Fig. 2–6. A cornstalk is a good example of a stem that is not woody. It has a hard covering, or rind, on the outside. Most of the stem is soft pith, through which are scattered fibers. Water and food pass up and down through the tubes in these fibers.

of all plant cells. Their hues are not like paint, merely on the outside of the parts of the flower. They are color substances produced in the cells of the flower, and sometimes they rival the sunset in their brilliancy.

40. What is the cellular structure of a green leaf? Under the microscope a leaf is seen to be somewhat like a sponge in structure. In the leaf are boxlike cells and also irregular cells, with spaces between them. The veins of the leaf are really ducts, continuations of those that bring water to the leaf from the roots and stem. Then there are cells guarding the thousands of small openings on the underside of the leaf. Through these openings, each of which is called a *stoma,* air comes into the plant and water, *carbon dioxide,* and *oxygen* escape into the atmosphere. [See Fig. 2–7.]

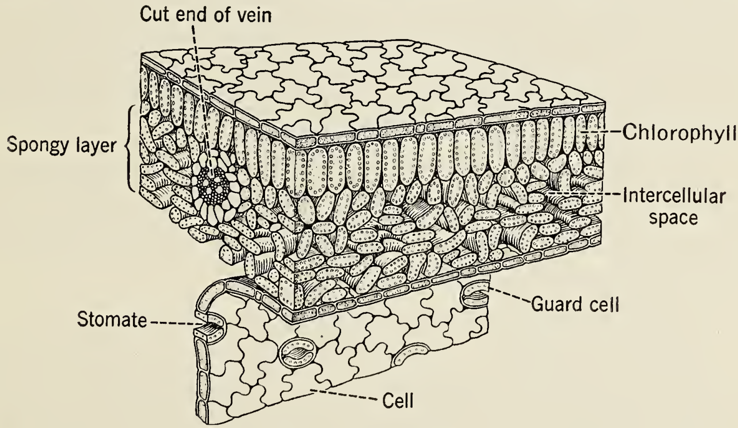


FIG. 2–7. A leaf, like all other parts of a plant, is made up of cells. In this diagram, a portion of a simple leaf has been enlarged enough so that we can see its individual cells. The lower skin has been partly pulled away. The palisade layer and the spongy layer are the regions where starch is made. Note the stomate openings through which air comes into the leaf, and the cut-off vein through which water is brought up from the roots into the leaf. A simple leaf, under the microscope, is amazingly complex.

41. What activities do roots perform? Unless the roots did something for the plant, they would be of no use. What *functions* do roots perform other than holding the plant firmly in the ground?

If one cuts off the root of a growing plant, unless it is a vigorous weed, the plant soon wilts and eventually dies. It is evident that roots are necessary for the life of plants. Roots absorb moisture from the soil (soil water) and send it up through the ducts of the roots and the stems into the leaves. It is also known that many roots store up food – the roots of the carrot, beet, sweet potato, for example, and many others.

42. What functions do the stems perform? Stems, by their woody tissues or by their rind, are able to support the bulk of the plant above them. They contain ducts through which water is carried up to the leaves, and sieve tubes by means of which digested food is carried down into the lower part of the stem or the roots. Some air is taken into the plant through the openings in the outer bark.

Some stems make or *secrete* special substances like resin, gum, oil, or sap. Some of these substances have been found to be of great value to mankind. Rubber is one of the most important of such plant *secretions.*

43. What functions do green leaves perform?

a) *Starch making.* As you have found out, most of the leaf cells contain an abundance of the green substance, chlorophyll. When chlorophyll is present, if the living plant has plenty of carbon dioxide and water, the living cells of the leaf accomplish a most remarkable thing. If the stomata in the underside of the leaves are open, as they usually are, air containing carbon dioxide is bound to enter the leaf. Water constantly comes up into the leaf through the ducts. Now the cells of green leaves accomplish an amazing thing, which

neither you nor even the teacher of your class can do. *Out of just water and carbon dioxide the cells containing chlorophyll, when in sunlight, can make starch.*

b) *Protein making.* The starch can be changed into sugar. Then by adding to it some chemicals taken from the soil water, the plant cells can make still another food substance. This is called *protein,* and it is used both by plants and animals in the making of new cells and repair of old cells. Some plants can also make oil.

c) *Digestion.* After starch, protein, and oil are manufactured, the living cells of the leaves digest them. *Digestion* means the changing of a food substance into such a form that it can be used either to make more cells or to give *energy.* Digestion can take place in almost any living cell of the plant. The plant takes in much water through the roots, and some of it escapes, as vapor, from the leaves. When the stomata are wide open, invisible water vapor is passing off into the air constantly. You can prove this easily by filling a tumbler with water, then placing a card with a hole in it over the top. In this hole insert the stem of a vigorous leaf. Then place a dry tumbler inverted over the first tumbler and the leaf. Place the tumblers in the sunshine, and in a few minutes, you

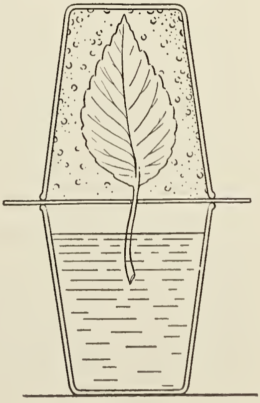


FIG. 2–8. A live green leaf is constantly giving off water in the form of invisible vapor. When the stem of a vigorous leaf is placed in water, in a tumbler topped with cardboard and covered with another tumbler, this vapor changes to drops of water. These drops can be seen on the inside of the upper tumbler if the tumblers are placed in the sunshine.

will see beads of water forming on the inside of the upper tumbler. It is well to have a *control* experiment set up exactly similar except that no leaf is used. This passing of water from the living leaves of a plant is called *transpiration.* [See Fig. 2–8.]

d) *Oxidation.* Some of this digested food may combine with oxygen in the leaf cells and elsewhere in the plant. This is called *oxidation.* It results in producing a little heat, and in making possible a certain amount of energy for the growing plant.

44. What life functions are carried on by living plant cells? How can you distinguish between a living thing like a growing bean plant and an entirely lifeless thing like a stone? Just what are the differences and how can one tell whether or not a certain thing is alive?

Biologists have learned that living things:

a) require food
b) change this food by digestion, unless previously digested, so that their cells can use it
c) circulate this digested food
d) repair cells, and grow by making new cells out of the digested food
e) take oxygen into the cells
f) oxidize food, thus producing heat and releasing energy
g) *excrete* waste materials formed in the cells by oxidation
h) secrete various liquids
i) *reproduce* offspring usually resembling the parents

In addition to these functions, animals can usually move from place to place, and they have nervous reactions. Plants rarely move, and they do not have the nervous reactions of animals. However, a plant known as the *sensitive plant* and a few others fold their leaves when touched. On the other hand, green plants can manufacture food (starch, sugar, protein, and oils) – something which no animal can do.

It should be added that each living cell of the plant generally performs these nine basic functions. It is quite right, then, to regard the cell, in a plant, as the *unit of function* as well as the unit of structure. This will be just as true of animals as it is of plants.

QUESTIONS

1. Find out the name of the man who invented the microscope, and some facts about his life.
2. Which is the harder wood, pine or oak?
3. Can you name any lifeless parts of a cell?
4. What are the sources of the carbon dioxide in the air?
5. Can you tell several reasons for believing that a stone is not alive?
6. What is meant by the statement that "the cell is the *unit* of structure and of function"?
7. Can you name a plant that consists usually of only one cell?
8. Can you name an animal that consists usually of only one cell?
9. What function can grass perform that a person cannot?
10. What functions can a person perform that grass cannot?

SOME THINGS FOR YOU TO DO

1. Sprout some bean seeds by keeping them in moistened sawdust. From one well-sprouted seedling which has root and stem, carefully cut off the plump, food-storage places, or *reservoirs* (rĕz′ẽr·vwôrz). These are the two parts that look like peanuts. Select another sprouted seedling, but do not cut away any part. Now place these two seedlings on a cork over a tumbler of water, into which the root of each can dip through a hole in the cork. Be sure that water is added each day to the tumbler. See which seedling grows better. What does this experiment show you about the plant's food reservoirs?

2. When the trees are budding, make a whistle from willow or from basswood. Select and cut off a small, smooth branch from one half inch to one inch in diameter. About two or three inches from the end, cut a ring through the bark all around the branch, with a sharp knife. Now make a fairly deep horizontal cut across the top about one inch from the end. By a slanting cut make this into a notch. Then cut off the lower end of the branch by making a long slanting cut underneath. [See Fig. 2–9.]

Fig. 2–9

Now gently pound the bark with something like a knife handle, between the ring and the end, until a twist or two loosens the bark and it slips off the wood. Then cut away some of the wood behind the notch. Also carefully take off a strip of wood from the notch to the outer end, so that it is somewhat flattened. [See Fig. 2–10.]

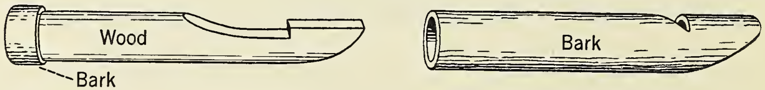


Fig. 2–10

Slip the bark back on the wood, and you should be able to blow your whistle. When you are not using the whistle, keep it in water; otherwise the bark will crack.

Animals Too Are Interesting Neighbors

WHICH is more important, a plant or an animal? Both plants and animals are important, but animals can move about; they have interesting structures and colors; they make sounds; some of them even show affection for persons. In all these ways they appeal to us.

In this unit you will study the ways in which animals differ from plants. You will study some of the interesting ways in which animals differ from one another, and how they use their remarkable equipment.

As you study about animals, you will think about the animals that are your own friends; perhaps about other animals such as the dog that the shepherd finds so trustworthy, and the horse that has helped man for centuries. Yet the consciousness of all of these friendly animals is limited. No one of these animals is conscious that he is an animal. Man has made the word *animal*.

No other living creature has self-consciousness as has man. Biologically he too is an animal, but mentally and spiritually he is as far above the horse as the horse is superior to the dandelion. Human beings have greater ability than the lower animals have; they also have greater responsibility to develop their powers both for the sake of their personal growth and for the sake of increasing the happiness of others.

Think about these!

1. Can you tell the footprints of birds from those of fur-bearing animals? From these footprints, can you tell in what direction the animals were moving?

2. Do you know the names of ten wild animals to be found within five miles of your home? (Remember that a fly is a wild animal.)

3. Do you know what birdbanding is?

Words for this chapter

Grub. The wormlike stage following the egg in the life history of such insects as the beetle.

Colonial (kȯ·lō′nĭ·ăl). Living together in a group.

Locomotion (lō′kȯ·mō′shŭn). Moving about, as most organisms do.

Tentacle (tĕn′tȧ·k'l). A slender part of certain animals, capable of motion in any direction.

React. Respond to.

Carcass. The body of a dead animal.

Dinosaur (dī′nȯ·sôr). A prehistoric animal related to modern reptiles.

Aquatic (ȧ·kwăt′ĭk). Living in or belonging to water.

Membrane (mĕm′brān). A kind of skin.

Vertebra (vûr′tė·brȧ), *plural,* **Vertebrae** (vûr′tė·brē). One of the small bones in the spine.

Vertebrates (vûr′tė·brāts). The higher animals, having a spine, or spinal column.

Invertebrates. The lower animals, having no vertebrae.

CHAPTER 3 ________________ UNIT 2

What Animals Do You Know Well?

45. How can we meet wild animals? Animals, unlike plants, do not usually remain in one spot very long. They get hungry and have to seek food. Also, enemies may come upon them and cause them to leave. Most wild creatures are shy. So, in getting acquainted with wild animals, you will have to be patient and willing to get your knowledge slowly. Often the information will not be direct; that is, you will find only some trace of the animal you are looking for instead of finding the animal itself. It may be the footprint of a rat or a mink or a gull; it may be the tunnel of a mole; it may be the feather of a blue jay or the abandoned nest of a robin. Do not be discouraged if you do not see many wild animals at first. Think of the study of animals as a sort of game, in which you are matching your superior mind against the native cunning of the animal. Maybe you will not think your mind *is* so superior after you have been fooled many times by

wild animals. Every bit of information that you can find out about an animal, if you take the time to put it with the other facts you have already learned about that animal, will help you to know about its habits, its home life, its food, its enemies, and so on — in other words, to become acquainted with it where it lives.

46. Where do wild creatures live? Where animals live, and their habits of living, are more important in most cases than the names of the animals. For instance, chickadees, woodpeckers, and nuthatches are never to be found among the English sparrows squabbling in the streets. Instead, they commonly live in trees, especially in woods. The red-winged blackbird haunts marshy places; the barn swallow nests under eaves of country barns; the field sparrow chooses the meadow. [See Fig. 3–1.] As we know these and similar facts, we associate certain birds with certain kinds of regions. The common green grass snake is found in meadows, not

FIG. 3–1. The red-winged blackbirds get their name from the scarlet, yellow-tipped shoulders of the male. They are found in most parts of North America in swamps or marshy streams. The bird shown here is a female. (*Courtesy U. S. Department of the Interior*)

Fig. 3–2. This is a very unusual picture, for one doesn't often find a woodchuck sitting up beside his hole for the camera. (*American Museum of Natural History*)

among the rocks which the copperhead and the rattler prefer.

Every country boy knows the burrow that betrays the underground home of old woodchuck, the clever fellow who steals into the unprotected garden for generous samples of lettuce and other tender things. [See Fig. 3–2.] The fox also has a den, but he did not dig it. He finds a rocky retreat to his liking, and then moves in. Beavers are seldom found away from water. They can be discovered by means of the dams they construct in order to flood their houses, and by the curiously gnawed-off trunks and branches of trees. [See Fig. 3–3.] The wood frog and the toad are found in dry places, though they both began their life in the water. The bullfrog and the green frog, on the other hand, never leave the water. Do you know the salamanders, wrongly

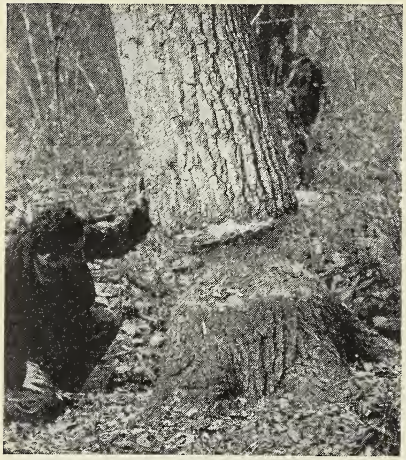


FIG. 3–3. It is easy to see that a beaver has been at work here. He and perhaps some of his friends have been gnawing at the tree shown in this picture. Why did the beavers gnaw all the way around the trunk? How does this method compare with the method used by lumbermen? (*Courtesy U. S. Department of the Interior*)

called lizards? They are smooth-skinned creatures with long tails, unlike their tailless cousins, the frogs and toads. They are found usually in moist places. Some salamanders can move with incredible speed.

47. **What are some guides to wild animals?** Animal stories and accounts of animals written by others who are more experienced than you, will be a great help. There are many interesting books, suited to readers of different ages, in which animals are pictured and described. In many towns and cities there are museums to visit. But nothing can take the place of learning about animals through your own observations. At first you will need considerable help from a scout leader, your teacher, or your camp counselor, all of whom can help you in many ways. You will learn the value of a pair of field glasses or opera glasses in studying birds. You will learn to treasure a good magnifying glass for examining tiny things. You will also realize the importance of keeping a sort of diary or journal of what you see and learn, written in your own words.

48. **What records will you keep?** Your notes should include facts based as far as possible on your own observations.

You should find out whether the animal stays by itself or goes around as a member of a group of its kind. For instance, a chipping sparrow, a weasel, a mosquito, and a black snake are all solitary animals. On the other hand, crows, wolves, and mackerel like to go in crowds of their own kind. Can you sketch the animal, or at least describe it accurately as to size and markings? Do you know anything about the teeth of the animal? If you can see a skull and look closely at the teeth, you will learn something about the kind of food that the animal eats. Animals like the dog and cat have teeth with *cusps*, or sharp points, for tearing animal food. Tiny, slender teeth, such as those of the snake and frog, are valuable for holding small creatures which they capture for food. The rodents, such as squirrels, rats, and beavers, have two chisel-shaped teeth in the upper jaw and two similar teeth in the lower jaw for gnawing nuts, wood, and bark. These are *incisors* (ĭn·sī′zẽrz). [See Fig. 3–4.]

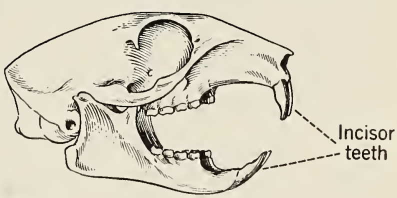


FIG. 3–4. The hard enamel makes a sharp cutting edge for the four chisel-shaped incisor teeth of rodents. Thus the rat, mouse, porcupine, and beaver are well fitted to gnaw wood and nuts.

49. What can you learn from an animal's feet? If you can look at the feet of an animal, you can learn much about its method of catching prey. The cat and its relatives have padded feet and move silently. They also have strong curved claws for fighting. The gulls, ducks, and frogs have webbed feet for assistance in swimming. The mole has big front feet with strong claws so that it can quickly dig through the earth and get worms, *grubs*, and roots for food. The horse has four strong hoofs to support his great weight. The

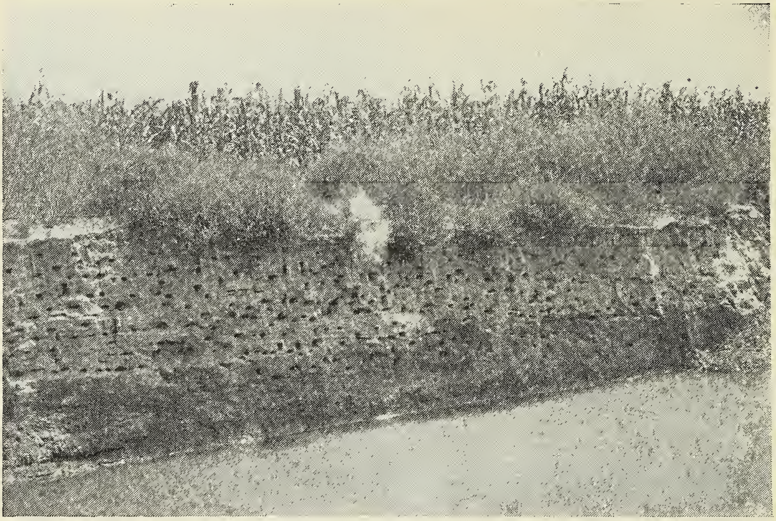


Fig. 3–5. Most birds build their nests in trees and bushes, on the ground, or around barns. Have you ever seen nests like these built by bank swallows? (*Courtesy U. S. Department of the Interior*)

Rocky Mountain goat has small, black hoofs, each divided into two parts. This animal, like the mountain sheep and the chamois, climbs with ease up and down over precipices and ledges too steep for man to climb.

50. What do you know about the home life of wild animals? Facts about the home life of animals are also worth knowing and recording. You should find out where and how the animals raise their families. Most birds build nests; some, like the kingfisher and the bank swallows, tunnel into the bank. [See Fig. 3–5.] Some, like the piping plover and nighthawk, make no nest at all, but lay eggs in a cavity on the ground. Field mice rear their blind, pink, hairless young in a round mass of dead grass. [See Fig. 3–6.] Sometimes the bumblebee uses one of these abandoned nests for its own. The bear likes a cave in the rocks. Lower animals have less home life, and in many cases do not even know their own

FIG. 3–6. These eight baby field mice have just been taken from the nest. After several days their eyes will open, and hair will appear on their bodies. (*Courtesy U. S. Department of the Interior*)

babies. Frogs, fishes, and insects as a rule lay their eggs and then rarely have anything to do with their young. The *colonial* insects, like bees, wasps, and ants have wonderfully organized homes where thousands of individuals live peacefully. Here great care is given the young.

The largest baby in the world is a newly born whale. One of the smallest is the opossum — so small that eighteen baby opossums can rest in a teaspoon! [See Fig. 3–7.]

51. How well do you know domestic animals? Have you ever thought how many different breeds of dogs, cows, horses, cats, sheep, goats, pigs, and pigeons have been developed under man's care? Have you ever imagined what the wild ancestors of all these animals were like? You may find for your notebook amazing things about domestic animals.

Do you know the difference between the so-called "hollow" horns of the cow and the solid antlers of the male deer

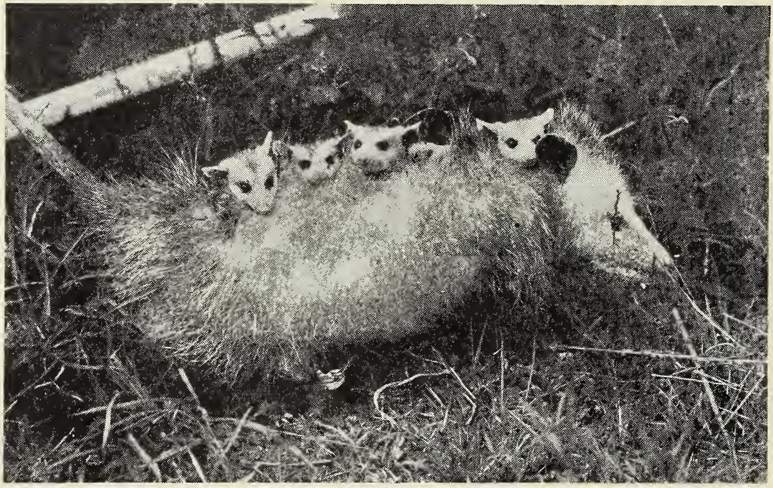


Fig. 3–7. These opossum babies are riding on their mother's back. Sometimes the mother curls her tail up over her back and each of the baby opossums coils its own tail around the big tail and hangs on like a "straphanger" in a trolley or a bus. (*Courtesy U. S. Department of the Interior*)

or stag? Are you aware that the cow keeps her original pair of pointed horns throughout life, but that the stag drops his beautiful pair of antlers every year? And do you know what a cow is doing when she chews her cud? A cow has four stomachs. She eats plenty of grass, then lies down; and the grass which she has swallowed into her first stomach comes up into her mouth to be thoroughly chewed. Afterward it is again swallowed, and this time it goes into her second stomach. Probably you have had a cat or dog lick your hand. The tongue of each of these animals is somewhat rough. But the tongue of a cow is much rougher, almost like a broad file. This helps to grasp the blades of grass, and you will probably long remember the experience if you should happen ever to be licked by the tongue of a cow. Did you know that one can tell the age of a horse by the condition of the ridges in

the teeth? Men who know much about horses actually use this method in buying a horse.

52. How would you describe your pet animal? Every boy and girl has a pet animal of some kind, or has had such a pet. Those who have such an animal friend know it so well that if it were lost, they could give a very accurate description of it, including size, color, and special markings or peculiarities. Some facts could also be furnished about its habits or ways of living, its food, what it would do if this or that happened, and its likes and dislikes. You will notice that your description concerned first the body, or structure, of the animal chosen, and then its activities. If you were telling about some wild animal which you knew, you probably could also say something about its home, wanderings, probable length of life, relations to other animals, and so on. [See Fig. 3–8.]

53. Would you mistake an animal for a plant? Animals, like plants, are alive. In fact, because most animals move about and do so many things, we are likely to think of them

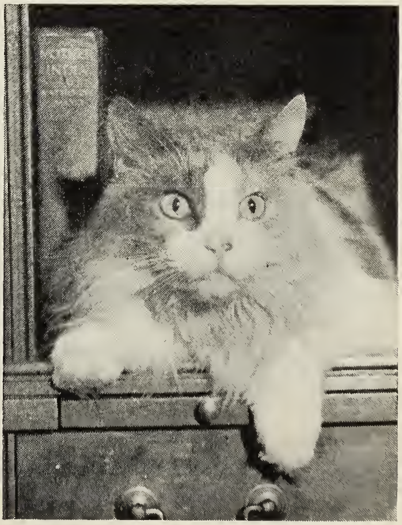


Fig. 3–8. Isn't this a beautiful cat? Have you ever noticed a cat's eyes when he runs in front of the headlights of a car on a dark night? Do you know why a cat can see better than you can in the darkness? If you have had a cat for a pet, you know how independent cats are. They seem to have kept more of their original wildness than have dogs. What wild habits have you noticed in a cat? (*Philip Gendreau*)

as much more alive than plants. But we know very little about life and its strange powers, even though we ourselves are alive and see living things every day.

Think of the definition of a plant given in a preceding chapter. Now think of some common animal. How many of the characteristics of plants are true of that animal? An animal certainly does not have roots, stems, leaves, flowers, or fruits. Animals are not generally green in color. No – animals as we see them do not resemble plants. No one would ever mistake a cow for a tree. [See Fig. 3–9.] Yet there are some animals which are so much like plants that for many years they were thought to be plants. The sponges, for instance, were for a long time regarded as plants. Even today, in fresh-water ponds, there is a microscopic organism (a form which can be seen only through a microscope) called *Volvox;* the botanists call it a plant, and the zoologists call it an animal.

FIG. 3–9. You can easily distinguish between the cows and the trees in this picture. Can you tell the principal differences between a cow and a tree? (*Courtesy The Borden Co.*)

54. How do animals differ from plants? Let us name as many as we can of the characteristics by which we distinguish animals from plants.

a) *Locomotion.* Perhaps the most important difference between animals and plants is that most animals can move about. Some animals, like the oyster, sponge, and barnacle, after a very brief youth in which they go freely through the water, settle down and never again stir from the spot to which they become attached.

When you know more about animals, you will realize why their bodies have to be very different from plants, since they have such structures as legs, arms, tails, *tentacles,* wings, and fins to help them in *locomotion.*

b) *The kind of food eaten.* All animals move about primarily to get food, but also to escape being eaten by other animals. As you know, animals cannot manufacture their own food as can green plants. Hence they must eat plants or other animals. The fixed oyster and sponge must depend upon water currents to bring food to them.

c) *The structure of the body.* You will remember that the plant, throughout its structure, is made up of cells. If we examine under the microscope a thin section of any part of the body of an animal, shall we always see cells more or less similar? Animals, like plants, are made up of cells. But animal cells do not have the boundary wall on the outside of the cells as do plant cells. Therefore it is not so easy to see separate animal cells. For this reason, the discovery of animal cells was not made until many years after the discovery of plant cells.

d) *Nervous reactions.* Each of the larger animals that we see daily has a brain and a nervous system. By means of the brain and the nervous system, these animals know something of what is happening around them. Even the lower

animals that do not possess a brain *react* to occurrences about them, whereas plants rarely react. Even the tiny, one-celled creatures move away from heat and acids, though they are usually attracted by light. They like food just as well as you do, and usually move toward it when they find it and crowd around it until it is consumed.

55. What is an animal? Perhaps we are going to find it harder to define an animal than to define a plant. But we must try. You already know that most animals move about at some time in their life, that they have bodies fitted to help them to move, and that they cannot make their own food as plants (at least green plants) can. Also you know that both plants and animals are made up of cells, but that the cells of plants are more conspicuous because they have well-defined walls. All animals are more or less conscious of their surroundings and react in different ways to things happening about them. You are certainly aware that most of the animals you know react to their surroundings by special senses, such as sight, hearing, smelling, tasting, and feeling. All the special senses are connected with the brain through the nervous system. From these facts can you make up your own definition of an animal? What is your definition?

56. How do animals differ in appearance? In appearance, animals differ from each other probably even more than do plants. So far as size is concerned, the smallest animals are about the same size as the smallest plants. Both are microscopic, and just one cell big. Contrast with such a minute thing the huge *carcass* of the sperm whale, the mightiest animal in existence today. Full-grown sperm whales may be sixty-five feet long. The one shown in Figure 3–10 is a young whale, and is only eighteen feet long. Very few are now alive because so many have been killed for their oil and other products. Millions of years ago, enormous animals called *dino-*

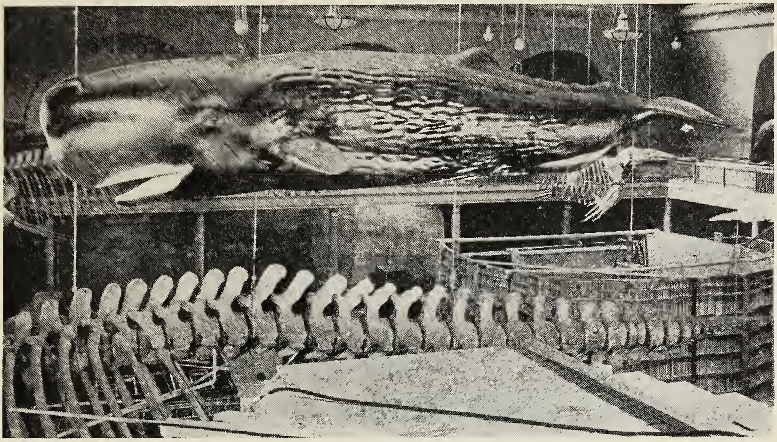


FIG. 3–10. A young whale mounted and suspended in the Hall of Oceanic Life in the American Museum of Natural History. Part of the skeleton of another whale can be seen below. (*American Museum of Natural History*)

saurs stalked through the land. From their fossil bones which have been found in rocks, it is evident that the dinosaurs were the largest of all creatures that ever lived on this earth. Dinosaurs were for the most part land animals, but the whale, as we know, lives in the water. There are evidences, however, in the structure of the whale's body, such as leg bones buried under the skin, which make us think that the ancestors of this *aquatic* creature may have lived on land.

Animals that live in the water are usually well fitted for that kind of life. They are provided in many cases with streamlined bodies so that they can slip through the water propelled by tail and fins; they have special coverings like scales or tough skin for protection, and special organs for breathing. Some animals which live in the air, however, are provided with wings instead of fins. Their bodies cannot be heavy, and they must have some means of flying, such as feathers, as the birds have, or *membranes*, as the bats and

insects have. Many of these creatures are also streamlined. Animals that live on the land usually have legs for running, and leaping, and climbing. Their skin may be rough or smooth; it is sometimes covered with hair. Many of the land animals have weapons such as horns, claws, or very sharp teeth to be used for offense and defense.

Animals differ greatly in the kind of teeth they have. We find toothless animals such as the anteater and the toad; animals with teeth in the upper jaw only, such as the frog; animals with front teeth in the lower jaw only, such as the cow and the sheep; animals who have two sets of teeth, such as the apes; animals whose teeth are replaced when broken off, such as the rattlesnake and the shark; and animals whose teeth project from the mouth, such as the walrus and the elephant. The front teeth of the beaver and other rodents, used for gnawing, grow rapidly and thus keep pace with the wearing away.

One of the most interesting things about animals is their difference in form, color, size, and habits. It is a constant delight for a student learning about animals to study their varying structures, functions, and activities.

57. What animals are called vertebrates? The interior of the bodies of animals may be as interesting as the exterior. For instance, fishes, frogs, reptiles, birds, and higher animals, all possess a line of bones extending down the back, popularly known as the *backbone*. Run your finger or knuckles up and down your own back. You find a series of little bumps in the middle of your back. Each of these bumps is a single bone, called a *vertebra*. Since you have twenty-four of these backbones, it is more accurate to speak of the *backbone* only when you mean one of these vertebrae. Animals that possess these *vertebral* bones in the back are called *vertebrates*. Vertebrates are the highest type of animals.

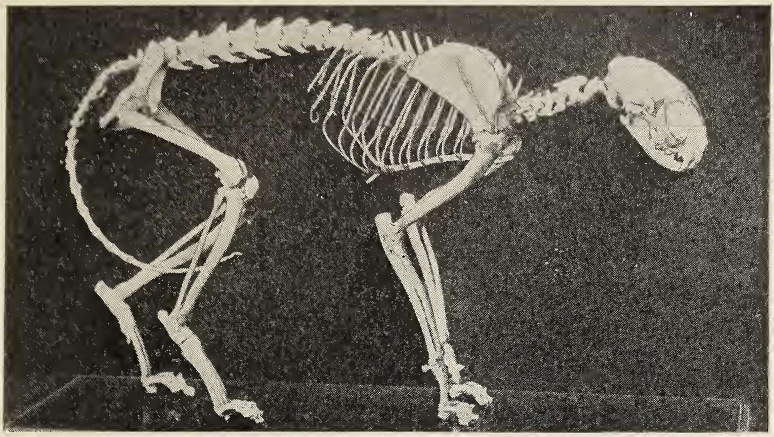


FIG. 3–11. Would you know that this is a cat's skeleton? (*American Museum of Natural History*)

They are not only generally larger than other animals, but they have more complex structures, and in many cases they show more intelligence. [See Fig. 3–11.]

58. What animals are invertebrates? Most of the animals in the world lack vertebral bones. Hence these animals are *invertebrates,* which means that they do not possess backbones. In fact, they do not have any skeleton, or bones within the body. Instead many invertebrates, such as insects, crabs, centipedes, and spiders have a sort of outside skeleton, composed of a specially stiffened layer, to which their muscles are attached. Other invertebrates are soft-bodied. Vertebrates have a main nerve cord extending along the back, inside the vertebral bones. Invertebrates, if they have any main nerve cord at all, have one on the lower side of the body instead of along the back. Many invertebrates live in water or moist places. Such aquatic animals include many one-celled animals; sponges; coral; sea anemones (ȧ·nĕm′ō·nēz); starfishes; most worms; many mollusks (mŏl′*ŭ*sks) such as oysters, snails, clams, and other animals

whose shells you find on the beach; and many kinds of insects.

Invertebrates greatly outnumber the vertebrates. There are over 700,000 kinds of invertebrates which have been named by scientists, and probably thousands yet undiscovered and unnamed. About 63,000 kinds of vertebrates are known to science.

59. How have scientists grouped animals? Scientists have divided both vertebrates and invertebrates into many different groups, called *classes*. Each class is also subdivided into *orders*. Each order, likewise, has divisions called *families*. Each of these divisions is based upon difference in structure. There are still other divisions, but they need not concern us now. The different kinds of individuals in any one group are known as *species*. For instance, the goldfish, which so many people have in a fish tank in their homes, is one species of fish; while the cod, which you may buy in the market, is a quite different kind of fish, and therefore belongs to another species. How many kinds of fishes can you name? Perhaps some of the boys who go fishing can name a dozen species. Actually, there are in this country about 1,350 species of fish — including fresh-water fish and salt-water fish. [See Fig. 3–12.]

How many wild birds do you know? There are over two hundred species in the United States. More than half of these species of birds can be seen in a city park, such as Central Park in New York City, during the migration season.

60. Why study about animals now? Wherever you live, you will meet animals, and unless you are unlike most persons, you will have friends among animals. Your friend on a farm may be a plowhorse or a pig or a toad; in the city you may know a likable milk-delivery horse. If you go to Arizona, you may see jewel-colored lizards; in the Maine woods you may meet a deer. The more you know about these ani-

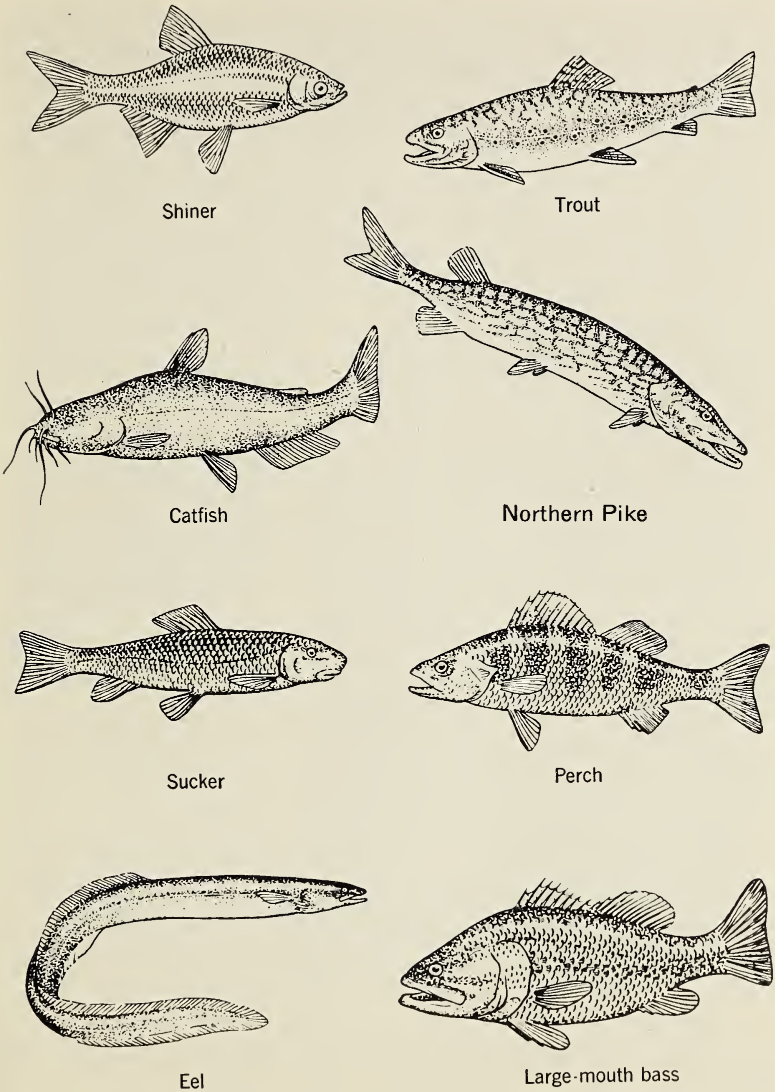


Fig. 3–12. Here are eight common fishes which many country boys and girls have caught. How many more fishes do you know?

mals, the more you will enjoy your experiences with them. Perhaps something that you know about an animal will help you to protect yourself or it. The sooner you learn interesting and useful things, the longer you can enjoy and use them. [See Fig. 3–13.]

If you went to a motion picture in which the actors spoke a foreign language, you would miss a good deal of the story. In the same way, if you are not acquainted with the nature and habits of animals, you will miss the " story " by not understanding their actions. You cannot speak a common language with animals, but you can learn enough to sympathize with them and to understand much of their behavior.

You will need to learn new words in your study of animals. But many persons who have studied the way our memory works think that at your age it is easier to learn new words than it will be when you are older.

QUESTIONS

1. Make a list of all the pet animals you have ever had. Describe one of these pets as accurately as you can.
2. What is the commonest wild bird you know?
3. How many wild birds do you know other than those mentioned in this chapter?
4. Do farmers in your locality kill snakes? Should they?
5. Do you know where in your state any natural history museums are located? What are the names of these museums?
6. Tell the name of an adult frog whose home is in the water.
7. Can you give the title of any book relating to animal wild life?
8. Has a toad teeth? What kind of teeth has a frog?
9. How could you tell, by looking at the teeth of the snake, that this animal could not bite its food into pieces as could a dog or a cat?
10. How do men tell the age of a horse by looking at its teeth?

Fig. 3–13. What do you know about caring for a dog? If someone gave you this friendly young terrier, would you be able to keep him healthy and clean and happy? Where could you find information about caring for dogs? A veterinarian would help you find out. (*Boyer from Gendreau*)

11. Does an animal have anything corresponding in structure or in function to the roots of a plant? Explain.

12. Does an animal have anything corresponding in structure or in function to the leaves of plants? Explain.

13. How many animal structures can you name that no plant possesses?

14. Most common plants are colored green. Why are not animals also green?

15. Why do you think that sponges were ever mistaken for plants?

16. How can men be sure about the size of prehistoric animals such as dinosaurs if no man ever saw them alive?

17. Can you think of any reasons why the invertebrates are more numerous than the vertebrates?

18. Can you name five species of invertebrates not mentioned in this chapter? What are they?

19. Can you name several species of vertebrates not mentioned in the chapter? What are they?

Some things for you to do

1. Make a permanent record of animal tracks by making plaster-of-Paris casts. You will need one tin can of one or two quarts' capacity, full of water, and another of the same size, empty; a strip of cardboard or a band of copper or tin about one and a half inches wide and eighteen or more inches long; a stick for stirring; a small can of talcum powder or a can of light automobile oil; and a can of plaster of Paris.

Find footprints or tracks of birds and other wild creatures in mud or sand. Dust the ground around one of these tracks with talcum powder, or pour or spray a little oil on it. Place the strip of cardboard or tin around the track like a fence, either pushing it down into the ground or making a wall of mud or sand around it. Do not put the strip so close that it spoils the track when the strip is pushed down. Mix the plaster, in the empty can, pouring water from the other can and stirring until the mixture is about

as thick as pea soup. You will need less than half as much water as plaster. Pour the plaster into the track and let it stand for twenty minutes or more, until it is hard; then remove the pasteboard or metal strip and lift up the cast. Do not clean off the mud or sand until the cast has hardened for several hours. The cast will be a negative, the reverse of the actual impression. After you clean it, you may write the date on it and perhaps the place where you found it and the name of the creature that made the track. In cold weather, tracks in the snow can be cast by spraying the track with water, and allowing it to freeze. Then pour in a cold plaster mixture.

2. Make a collection of the nests of wild birds, after the birds have finished using them. From Allen's *A Key to Bird Nests* or some other reference book find out what kind of bird built each nest, and label the nests.

3. Make a study of the kinds of hair found on three different species of fur-bearing animals.

4. Start a check list of wild birds, flowers, and trees, recording the name of each one, the date on which you see it, and the place where you see it.

5. Write a report on the kinds of teeth which three different species of animals have. If you can, make sketches to show the teeth. Tell the purposes for which each kind of teeth is used.

6. Write an imaginary story of a honeybee from the time of its hatching to the end of its short life. Tell the story in the first person, if you want to.

7. Have you ever reared a wild creature? If so, write an account of this experience.

Think about these!

1. Have you ever heard of an animal with a boneless tail?
2. Did you know that the snake hears with its tongue?
3. Are there any animals that are cold-blooded?
4. How can an animal change grass into hair?

Words for this chapter

Adaptation (ăd′ăp·tā′shŭn). A part, or structure, fitted to perform some function.

Scale. A small, flattened structure.

Membranous (mĕm′brȧ·nŭs). Thin, like skin.

Nectar. A sweet liquid produced by most flowers.

Organ. A part, or structure, of an animal or plant, fitted for some special purpose. The heart and the leaf are examples of organs.

Gills (gĭlz). Organs for breathing under water.

Osmosis (ŏs·mō′sĭs). The passing of a substance through a wet, thin membrane.

Absorption (ăb·sôrp′shŭn). The passing of soluble substances through membranes.

Circulation. The movement of liquids, chiefly blood in the case of animals, throughout the structure of a living organism.

Hormone (hôr′mōn). A substance secreted by a gland in the body; hormones are necessary for growth and health.

CHAPTER 4 ________________ UNIT 2

How Do Animals Live and Grow?

61. Do animals and plants have the same parts and functions? In Chapter 2 you learned something of the parts of a plant and what things were accomplished by these parts. In this chapter we shall consider some of the many curious parts, or structures, of animals to find out how useful these parts are to animals.

You already know that animals are very different from plants in many ways. Most animals do not resemble plants, because their structures are different. Their ability to move about, their special senses, their habits, and their reactions to things that happen to them reveal how much more complex they are than are plants.

62. What is an adaptation? Wherever a structure is especially useful to an animal, it is called an *adaptation.* Fins of fishes, for instance, are adaptations fitting the fish for

swimming, or in the flying fish, for soaring. Likewise the antlers of the stag and the claws of the bear are adaptations. The wings of birds with their light, but strong, feathers enable birds to fly. Some think the colors of animals may also be an adaptation. Spots on the brown coat of the fawn help to conceal it. The brilliant colors of the male birds seem to attract mates.

63. What are antlers? As you learn more about animals, you will undoubtedly wonder much about some of the peculiar structures possessed by some animals. Many male deer, for instance, have antlers which are commonly called *horns*. We cannot say definitely just why the male, called the *stag*, has these huge growths on his head, while the female has none. It is certain, however, that they are an adaptation used by the stag in part as weapons of offense and defense.

64. Have you seen these strange claws and teeth? Likewise, the long claws of the lion, the tiger, and the bear really correspond to our fingernails and toenails. But they are so much larger and stronger that they can be used by these animals as a means of protecting themselves or their young, and are an adaptation for capturing animals for food. The curved claws of the South American sloth may be as long

FIG. 4–1. The sloth is a strange animal. He even sleeps upside-down. He cannot fall from his perch, because once his muscles are fixed it takes a conscious effort to move them. (*Courtesy U. S. National Museum, Photo by A. W. Clark*)

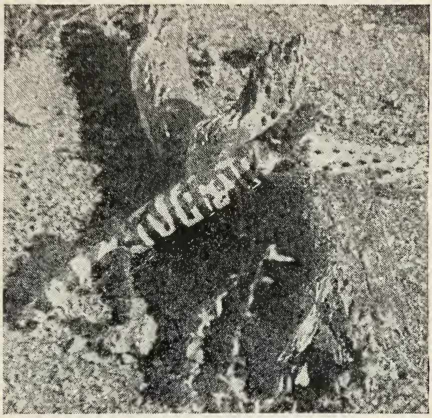


FIG. 4–2. The Gila monster is one of the largest lizards found in this country. The one that you see in the picture is looking out for food; but even if he finds nothing for some time, he will not starve. His tail is a storehouse for food, and he can go without food for months. The tail will grow smaller during that time. (*Underwood and Underwood*)

as your fingers. [See Fig. 4–1.] These claws are strong enough to hold the animal as it slowly walks along, hanging upside down underneath a limb. The teeth of animals like the lion, tiger, bear, cat, and dog have sharp points, or cusps, by means of which they can bite through muscle and even bone. But the teeth of the horse, cow, deer, and sheep, which eat grass or other leaves, are flat and provided with ridges. Thus these animals grind their food instead of biting and cutting it.

65. Have you ever seen a boneless tail? The long tail of the common fence lizard is so loosely jointed that it can easily break off in a struggle. Then the tailless victim scurries away and escapes, leaving a wriggling remnant with the enemy. A new, boneless tail grows in place of the lost member. The short and thick tail of the *Gila* (hē′lȧ) monster [see Fig. 4–2] of the southwestern United States, and of the stump-tailed lizard of Australia, serves a very different purpose. Such tails become reservoirs, where food can be stored for periods when food is scarce. The long tail of the South American monkey is better than a fifth leg because the tail can coil around a limb and cling to it.

66. How many kinds of wings do you know? Birds are provided with light, yet strong, wings. The bones that support these wings are hollow. The long quill feathers of the wings push against the air and enable the bird to fly. The butterfly also manages very well in the air through the use of another kind of wings. These wings consist of a thin membrane covered with the most beautiful *scales* imaginable. The "dust" which comes off on your fingers if you handle a butterfly by the wings (which you should never do, of course), consists of thousands of these scales. [See Fig. 4–3.] The bat, although covered with hair, has a curious skin between the front legs and the hind legs. When this is stretched tight, he can flit through the air much like the butterfly.

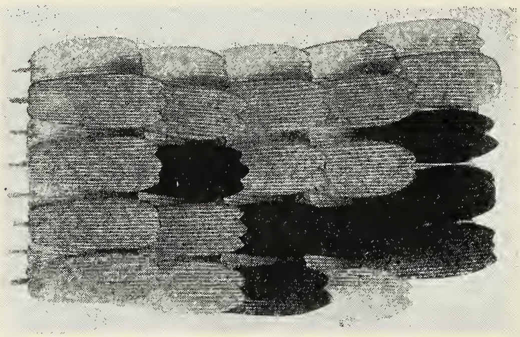


FIG. 4–3. This picture shows a model, greatly enlarged, of the scales on a butterfly wing. The scales are so small that they resemble powder. (*American Museum of Natural History*).

The flying fish has fins on his sides which are somewhat larger than the fins of most fishes. [See Fig. 4–4.] When this fish suddenly leaves the water, these fins can be spread in such a way that they act like the wings on a gliding airplane. Thus the flying fish may skim over the waves through the air for one hundred feet or more. The flying squirrel has a *membranous* skin stretching between the front and hind leg on each side. By this means he can toboggan down through

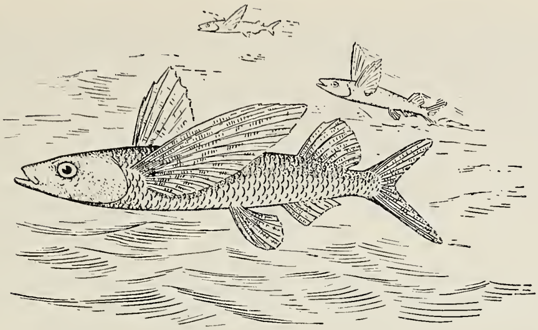


FIG. 4–4. The flying fish does not really fiy by moving his fins. Instead, he keeps them stiff and so glides through the air just above the water. Sometimes a flying fish may soar for a long distance.

the air from one tall tree to another lower down, or from the top of a tree to the ground some distance away.

67. Have you ever seen a leg with spines on it? Examine the hind leg of the next grasshopper you find and notice the little spines and claws on it. Have you ever seen the telephone workman who fastens a spike to each of his boots in order to climb the telephone poles? Remembering this, perhaps you can guess what the spines on the grasshopper's leg enable it to do. [See Fig. 4–5.]

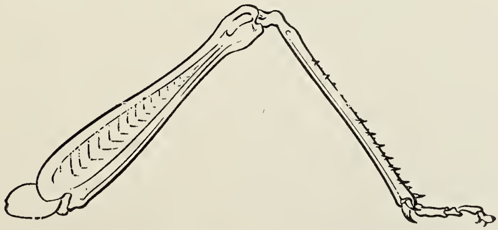


FIG. 4–5. We would not like to have sharp spines on our legs and claws on our feet. The grasshopper needs these structures to help him to climb the stalk of a plant and to hold on while he eats leaves and stems.

FIG. 4–6. The fawn is beautifully spotted, although its mother is not. The fawn loses its spots as it grows into an adult deer. (*Courtesy Bureau of Biological Survey*)

68. Have you seen these strange tongues? The anteater from South America has a long, sticky tongue. Its diet consists almost exclusively of ants. It will upset an ant nest, then sweep its long tongue back and forth among the hurrying multitudes of ants, bringing hundreds into its mouth at each lick. The common butterfly and moth also have a long tongue, which is hollow and somewhat spiny at the extremity. They push this tongue down into flowers to extract the *nectar*. The toad has a long, forked, sticky tongue attached at the front of the mouth. By this means he can flip the tongue out quite a distance to catch insects. The snake also has a slim, forked tongue which some persons think is a sort of stinger. However, it is entirely harmless, even in poisonous snakes. As a matter of fact, the tongue of snakes is a sort of sense *organ*. The snake keeps darting it out to get vibrations. The snake does not have true ears, and so we might say that the snake hears with its tongue.

69. **What animal do you think is the most beautiful?** What is the most beautiful animal you have ever seen? Some of you may have seen one of the rare birds known as birds of paradise. Someone else may vote for the peacock, when he spreads his magnificent tail. Someone else may remember a gorgeous butterfly from South America with exquisitely delicate wings, or the spotted fawn leaping down a woodland vale. [See Fig. 4–6.] No doubt the young mother, bending over her blue-eyed and flaxen-haired baby, thinks that no other living creature could be half so beautiful.

70. **What animals do you think are rather ugly?** Likewise there are many examples of animals that you might think rather ugly. There is the toadfish, a creature of grotesque appearance, and the hellbender, a horrid-looking creature. Some persons regard the common toad as a repulsive animal. Perhaps they have believed the superstition that this little creature can cause warts, which is impossible. Such persons should at some time look at the eye of the toad. If one has any sense of the beautiful, he cannot fail to appreciate the rich gold and black coloring which nature so strangely lavishes on this little creature. Shakespeare referred to the toad in these words: "The toad, ugly and venomous, wears yet a precious jewel in its head." [See Fig. 4–7.]

FIG. 4–7. If a toad moves into a drainpipe near your garden, you may congratulate yourself on your new neighbor. You could not find a better helper in gardening. The toad, with his swift tongue, catches and eats hordes of bugs that would harm your plants. The toad eats all night. (*American Museum of Natural History*)

No boy would ever kill a toad if he knew the great value of the toad in eating insects harmful to garden plants. Toads are among the best friends of man. So also are common snakes, because their chief food likewise consists of injurious insects. The common nonpoisonous snake is therefore valuable to man. The more that boys and girls know about these interesting animals, the less likely they will be to make the mistake of killing them.

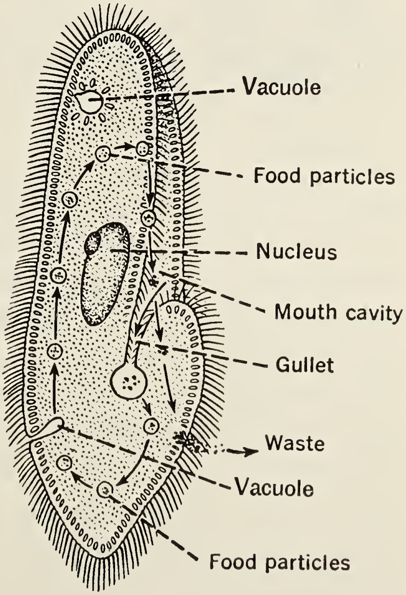
71. How do animals perform the life functions? We have learned that animals have all sorts of external structures called adaptations which fit them to live successfully. By means of special internal organs, they are even better adapted to perform the functions necessary to carry on an active life. The rest of this chapter will be devoted to animal functions, as they are performed by all animals, small and large.

72. Why do animals move about? The first function we shall consider is that of locomotion, or moving about from one place to another. This is usually done for the purpose of getting food or to avoid enemies, obeying a homing instinct, or merely for play. For this purpose most animals have muscles attached to bones or to the body wall. Some, like the starfish, jellyfish, and hydra, have slender tentacles. The squid shoots out a stream of water from a *siphon* (sī′fŏn), or kind of tube, under the mouth. This causes the squid to dart backward.

73. Why do animals eat? Whether they locomote or not, all animals must eat. [See Fig. 4–8.] Those that cannot seek their own food are usually not so successful in life. You know that starving animals are weaker than those that are well fed. They lose weight and strength. Animals that are kept from moving around are not likely to be as big as those that are free and active. Some of the food that animals eat is turned into muscles, skin, bones, and other parts of the body. A

FIG. 4–8. Do you know what kind of food elks eat? Here are a group of them feeding at a haystack while hay is being loaded. (*Courtesy U. S. Department of the Interior*)

FIG. 4–9. This is a one-celled animal called a *Paramecium* (păr′*ȧ*·mē′shĭ·*ŭ*m), found in ponds. Like higher animals, the Paramecium takes in food at the mouth. This food passes through the gullet into the interior. There is no true stomach; so the food particles are carried freely around inside the animal. Some of the food is oxidized to give the animal energy. Some is used to build new protoplasm. Any liquid waste is passed off from the two *vacuoles* (văk′ŭ·ōlz).



part of such food provides mineral substances for the making of coverings such as shells, and, in the case of the higher animals and human beings, certain substances that regulate the growth of the body. Some of the food also is combined with oxygen in the cells of the body, releasing real heat and energy. [See Fig. 4–9.]

74. Why do animals breathe? Air is just as important to every animal as is food. It does not matter whether it is a fish living in the water, a bird living in the air, or a worm living in the ground. Every animal must constantly have air from which to extract the precious oxygen. For this purpose, many of the animals living in the water, or animals that frequent the water, have *gills*. [See Fig. 4–10.]

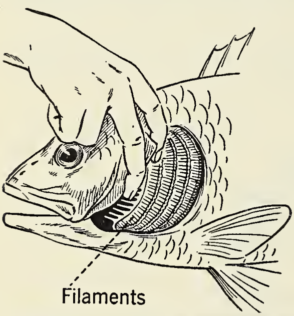


Fig. 4–10. The gills of a fish can easily be seen by lifting the gill cover. The gill filaments are so thin that oxygen from the water can enter the blood through the filament walls. The gas, carbon dioxide, passes off from the filaments into the water.

Structures like gills are very thin. Most other animals have special internal organs called *lungs,* the structures of which also are very thin. Some animals like the frog and the earthworm can carry on breathing through their skin if it is moist enough.

The food cannot combine with oxygen unless there is plenty of this gas in the body cells. When the food, or the protoplasm of cells, does unite with oxygen, heat is produced. This combination of oxygen with some other substance is, as you have learned, called *oxidation.* Those animals like the fish, frog, turtle, and snake, that have a very

low rate of oxidation are said to be *cold-blooded* animals. The higher animals like the cat, bird, dog, and human being, on the other hand, have a temperature a little below or a little above 100°, no matter what the surrounding temperature is. They are called *warm-blooded* animals.

75. How is the food digested for hungry cells? In almost all animals, food is taken in by the animal at a given place called the mouth. The process is called eating. Animals eat to satisfy a hunger which seems to come, at least in the case of so-called higher animals, from their stomachs. Hunger really starts in the different cells of the body, but it is noticed more in the region of the stomach, if the animal possesses that organ. Now a very interesting problem has to be solved. The food is taken into the body at one place only, but there are thousands, maybe millions, of hungry cells all through the body. How are they to get food?

The actual method is strange. First, the food must be changed by *digestion,* into a liquid state resembling soup. The food must also be altered in character, so that it can be used by the cells. Some digestion takes place in the stomach. Most digestion, however, occurs in the small intestine leading away from the stomach. The stomach and intestine are parts of the long food tube, or *alimentary* (ăl′ĭ·mĕn′tȧ·rĭ) *canal,* which extends through the body. In different places there are enlargements in this tube as though a river expanded here and there into a sort of lake. One of these enlargements is the mouth and another is the stomach. In the alimentary canal, special digestive juices are poured out on the food. These juices change the food to a liquid. [See Fig. 4–11.]

76. How does digested food get into the blood? Now this digested food must be carried to the cells. A special set of tubes, called *blood vessels,* extends throughout the body.

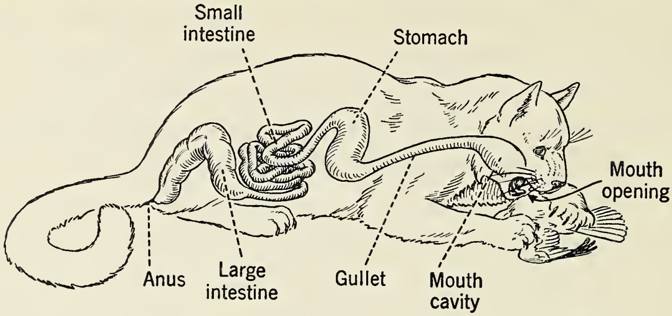


FIG. 4–11. The alimentary canal of an animal, well illustrated by this cat, begins with the mouth opening and ends at the anus. The food, taken into the mouth cavity, may or may not be chewed. In many animals, digestion begins in the mouth. As the food is swallowed, it passes through the gullet down into the stomach. Here it usually is mixed with gastric juice and digestion begins in earnest; it is completed in the intestine. As the digested food passes through the intestine, much of it is absorbed by the blood vessels. The remains of the food, of no value to the body, make up the refuse, which is cast off at the anus.

The liquid food soaks through the walls of the alimentary canal and then soaks through the walls of the blood vessels; thus food gets into the blood.

77. **What is osmosis?** When a liquid substance passes through a wet, thin membrane, the process is called *osmosis.* In this manner, digested foods pass through the thin, moist skin that lines the intestine and the blood vessels. We usually give the term *absorption* to this passing of food into the blood. Substances in the solid state do not pass through a membrane. And the membrane itself has to be thin and moist. Now you see why food has to be in a liquid form in order to pass into the blood.

78. **How does the digested food reach the cells?** The organ called the *heart* acts like a pump to send the blood all around the body. The cells in the hand and the foot must have the same chance for getting food that the cells of the

stomach and intestine seem to have. This movement of blood around the body is called *circulation.* Circulation is one of the most important functions carried on in the body, because by means of it both food and oxygen reach all parts of the body, all parts of the body are kept properly warm, and wastes are carried away from the cells. Thus life is continued. When the digested food, now in the blood, reaches the cells of the body, some of it goes by osmosis out through the thin walls of the smallest blood vessels, called the *capillaries* (kăp′ĭ·lĕr′ĭz). Then the food passes through the membranes of the cells into the interior of the cells, again by osmosis.

79. How is food changed into living cells? Cells in the body may be hungry because bodily energy is low, or they may be hungry because they need food material for their repair and growth. Certain kinds of food, especially protein, water, and mineral matter furnish just the right stuff out of which to make different kinds of cells. This changing of food over into the protoplasm of cells is called *assimilation* (*ă*·sĭm′ĭ·lā′sh*ŭ*n).

80. How do the cells get oxygen? Food enters the body of most animals at one place, the mouth. Oxygen, too, is taken into the body of most animals at one place. This is either the gills, as in the fish, or the lungs, as in the cat, or, in

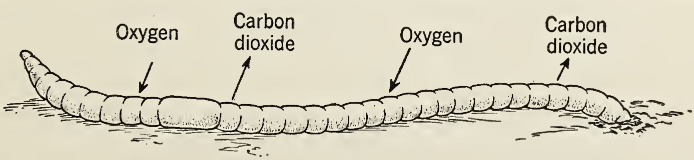


FIG. 4–12. By osmosis, oxygen from the air enters the body of an earthworm, and carbon dioxide passes off into the air. This exchange of gases takes place all along the earthworm's body, if the skin is moist. The early sun which dries the earthworm's body is as much an enemy of the earthworm as is the "early bird."

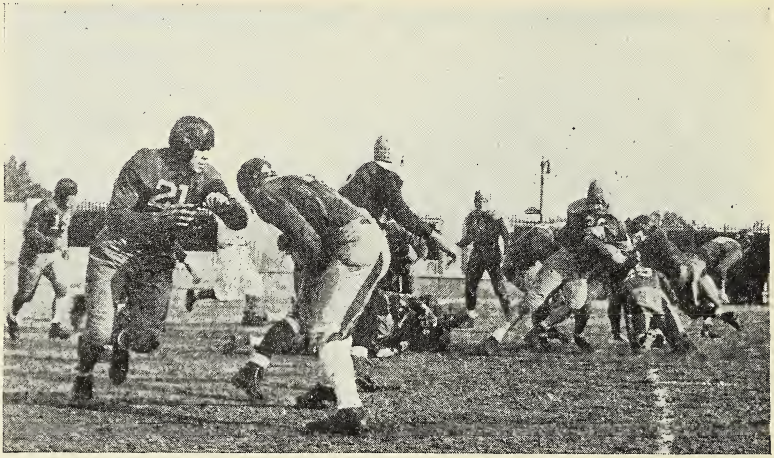


FIG. 4–13. Oxidation of food is necessary for the body to produce the energy required to carry on its activities. A game of football, or similar strenuous exercise, requires a great amount of energy. (*Ewing Galloway*)

a few animals such as the earthworm, the outer membrane of the body. The blood, as it flows through the thin tissues of the gills, lungs, or skin, absorbs the needed oxygen by osmosis. The oxygen is then carried around the body to the cells, into which it passes, as does the digested food, by osmosis. In a few animals, such as the insects, air comes into the body through holes and is carried around the body by means of tubes.

81. How do the cells use oxygen? If you light a candle, you soon know that the candle is being consumed, for you can see it slowly melt. You feel the heat produced, when you hold your hand over the flame. This heat is produced by the combination of oxygen with the substances of the candle. This combination, as you have learned, is called oxidation.

When food or protoplasm combines with oxygen in the living cells, the result is similar to the burning of a candle.

A certain amount of heat is produced. Energy is also released. [See Fig. 4–13.]

82. How do the cells get rid of waste products? When food or protoplasm is oxidized in the cells, certain left-over substances, or wastes, are formed. These substances must be got rid of, since they would act like poisons if left in the body. So the blood, on its return from delivering food and oxygen to the cells, picks up these waste substances and delivers them to certain organs to be cast out of the body. The watery waste called *urine* (ū′rĭn) is brought to the kidneys, from which it is carried to the bladder before it is passed off from the body. The gas, carbon dioxide, is passed off from the body through gills or lungs, and sometimes through the skin. The process of getting rid of wastes from the body is called *excretion.*

83. What is the secretion of substances? Just as plants produce and secrete certain liquids and products within the plant, so animals also secrete substances. For instance, *saliva* (sȧ·lī′vȧ) is a digestive juice produced in the mouth of all higher types of vertebrates. Likewise, gastric juice in the stomach and bile in the liver are two other secretions. In addition to digestive secretions, some organs in the body secrete substances called *hormones.* These substances are needed for normal development. They are absorbed by the blood and thus are carried around the body.

84. What is reproduction? Animals, like plants, have offspring. In most cases, the offspring have two parents. In many of the lower animals there is only one parent. Reproduction is such an important function that an entire chapter will be given to it later.

85. Why do animals behave as they do? Animals have one quality very different from plants. You know that animals react more definitely and more quickly than plants.

FIG. 4–14. The police dog is guiding his owner, who is blind, from the airplane. He is one of the famous Seeing Eye dogs who are trained to use their eyes for people who cannot see. The almost-human intelligence and dependability of these dogs make them seem able to think. Have you ever seen an animal — a dog or cat or horse — do something which seems to show thought? (*Courtesy Seeing Eye, Inc.*)

They do so because they are sensitive to their surroundings. Animals that are higher in the scale of life have what might be called nervous reactions. Even if they do not reveal much intelligence, most animals do express a certain amount of feeling and determination. Human beings have the capacity (not always used) to consider the facts and to act with judgment, that is, to *think*. Animals such as dogs, horses, cows, and even pigs give evidence of stopping to think. Noticing things in the environment and choosing proper action help in avoiding dangers. Feeling, thinking, and willing are sometimes called the mental functions, since they help the human being or the animal to relate himself to his surroundings, that is, to be aware of his surroundings and to act accordingly. [See Fig. 4–14.]

QUESTIONS

1. Is a bear's claw a bone or a kind of hardened skin?

2. How is a tail useful to a cat or a dog? (Is a bobcat as successful in life without a tail as an animal with a tail?)

3. Does the flying fish really fly? Find out all you can about the flying fish, in an encyclopedia or other reference book, and report to your class.

4. Do you know of what material the scales on a butterfly's wings are made?

5. Can you name several adaptations not mentioned in this chapter? What are they?

6. Can you name any young animal other than the fawn, which is different in color from its parents? What animal is it?

7. Do you know Aesop's fable about the bat, when the beasts and the birds were at war? Read it if you have not done so.

8. Name an animal with spines on its legs.

9. Would the rate of oxidation be more or less rapid in a cold-blooded animal than in a warm-blooded animal? Explain.

10. Some animals like frogs, snakes, and bears *hibernate* (hī′-bẽr·nāt), or go to sleep, during the winter. How do you think their rate of oxidation would vary from the normal, if at all, during hibernation?

11. What kind of food is necessary for the development of a sound and strong human body?

12. What kind of food is good for the release of energy in the body?

13. What do you think would be the effect on a person's weight if assimilation went on faster than oxidation?

14. Can you give any examples of what you regard as intelligence in animals? Explain your answer fully.

15. If man is more intelligent than the other animals, how do you account for the instances when he does not act intelligently?

SOME THINGS FOR YOU TO DO

1. Make a collection of different insects. Dropping an insect into a little gasoline will quickly kill it. (Remember that gasoline should never be used near a flame.) Look for as many adaptations of structure as you can find.

2. Shape a cell out of glycerine soap. Make a hole and push a marble in toward the center to represent a nucleus.

3. By means of a glass tube, blow your breath through some clear limewater. The change to a milky color is produced only by carbon dioxide. What produced the carbon dioxide in your breath?

4. Place your left hand on your upper right arm. Note the degree of warmth. Then bend your right arm rapidly twenty times. Now feel your arm. There has been an oxidation of substances in the muscle cells, which has produced extra heat. You can feel this heat.

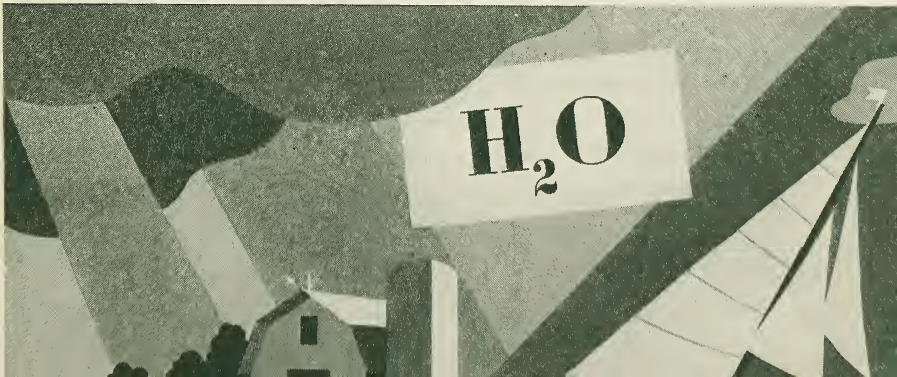
5. Very carefully measure your height at night and in the morning. Convince yourself as to whether or not you are taller in the morning.

Water Is Our Most Plentiful Liquid

COULD you live longer without water or without food? *Without food is the right answer.* You could live for only a few days without water. Water is necessary to the life of animals and plants, too.

Think how often you use water aside from drinking it. You use it for keeping clean; perhaps you use it in the heating system of your home. You travel over water; you use it for recreation when you swim or sail; you use frozen water, or ice, to skate on. You take quantities of water when you drink milk or fruit juice, or when you eat lettuce, squash, cucumbers, apples, potatoes, tomatoes, watermelon, and dozens of other foods.

Water occupies a large part of the world. This unit will tell you how much of the world is water. It will tell you how water changes its form; how water becomes rain and helps plants to grow.



You will find out also how the chemist uses water to dissolve chemicals and how he separates water into its elements and gets two gases from it.

You will read how water is used as a standard of measurement: the thermometer, which measures temperature, is based upon the boiling and the freezing points of water; and a system of weights is based upon the weight of water.

THINK ABOUT THESE!

1. Do you, as a dweller upon the land, have a larger area over which you can roam than does a fish which lives in the sea?
2. If you found an iceberg floating in the ocean and chipped off a piece of the ice and melted it, would the water thus formed be salt water or fresh water?
3. How is dew formed?
4. Is there any water in a potato?

WORDS FOR THIS CHAPTER

Horizon (hȯ·rī′z'n). That line where the sky and earth seem to meet.

Evaporate. To change from a liquid to a vapor or a gas.

Seep. To run or leak through.

Geyser (gī′zẽr). A spring which throws out boiling water and steam at intervals.

Vapor (vā′pẽr). A substance in the form of gas.

Iodine (ī′ȯ·dīn). A substance used in medicine as an antiseptic. It is sometimes extracted from seaweeds.

Potash (pŏt′ash′). A substance obtained from wood ashes and used in fertilizers.

CHAPTER 5 ——————— UNIT 3

Where Is Water Found?

86. What is the water hemisphere? In your study of geography you probably heard the terms *water hemisphere* and *land hemisphere.* The names are not very accurate, because the word *hemisphere* means *half a sphere* and the water hemisphere, which refers to the water area of all the oceans, certainly occupies *much more than one half* the entire surface of the earth. Think of a plot of ground one mile long and one mile wide. That is one square mile. Multiply that square mile by the number 197,000,000, and you have the number of square miles in the entire surface of the earth. That amounts to a little more than 125,000,000,000 acres. There are more than ten city lots 40 feet wide by 100 feet deep in one acre.

A little more than one-fourth of the surface of the earth is land. A little less than three-fourths of it is covered by water, to a depth of about six miles in some places. The Pacific Ocean is larger than the land areas that would be formed if

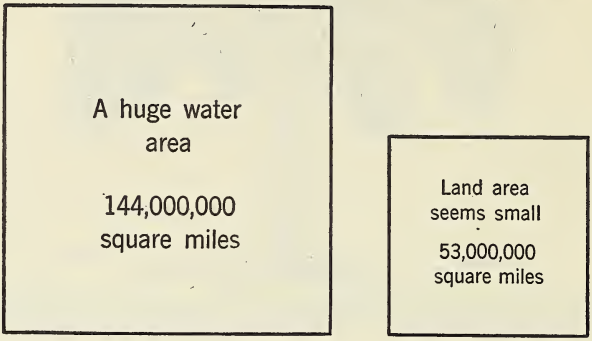


FIG. 5–1. Much of the surface of the earth is covered with water, and the oceans serve as a huge storage place. Do you know how we get rain from this water?

we put together all the continents and all the islands of our globe. Another huge continent the size of Asia would be required to make the land area equal to the area of the Pacific Ocean. [See Fig. 5–1.] The Atlantic Ocean, which is only half the size of the Pacific Ocean, is bigger than four continents the size of all North America. Ten countries the area of the entire United States would not be big enough to cover the Atlantic Ocean. [See Fig. 5–2.]

A woman traveling on one of the large ocean liners looked out at the broad waters of the Atlantic Ocean. No matter

FIG. 5–2. The United States would not make a very big island in the Atlantic Ocean. It is not surprising that Columbus and his sailors needed ten weeks to cross the Atlantic Ocean in sailing vessels, although steamships can now cross in four days.

which way she looked, there was no land within her *horizon*. Nothing but water, water, everywhere she looked. Then she remarked, " Isn't it a pity that there is so much water everywhere? Think of all the farm land this ocean would make." Suppose you take a few moments to think about her statement. Do you agree with her that the ocean should have been farm land? Possibly you cannot think of any logical reason now for challenging her statement. If you cannot, turn back to it again after you have studied something about the *water cycle* in the next chapter.

87. Have you ever seen one of the Great Lakes? We have been discussing the huge salt-water oceans. The small lake or the river that is near your home may seem merely like a " drop in the bucket " compared to them. When we see our rivers at flood stage, we begin to realize that they carry a large volume of water too. Minnesota is a state that boasts of 10,000 lakes. Some of them are a number of miles in length. Between Canada and the United States lies Lake Superior, the largest body of fresh water on the earth. [See Fig. 5–3.] This lake is more than four times the area of the

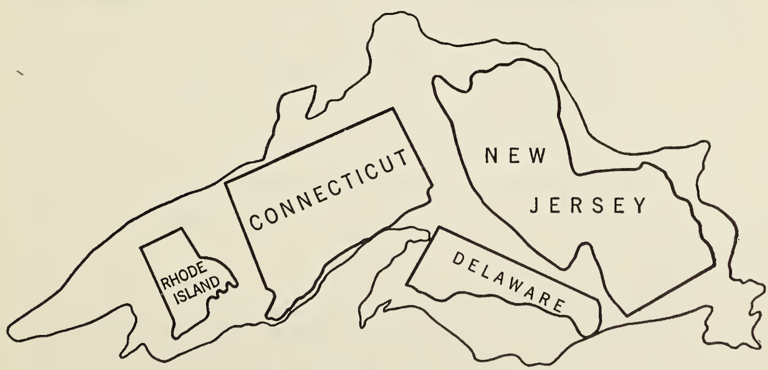


FIG. 5–3. This diagram shows the relative size of Lake Superior to four states. It is easy to see from this why someone named it Lake Superior.

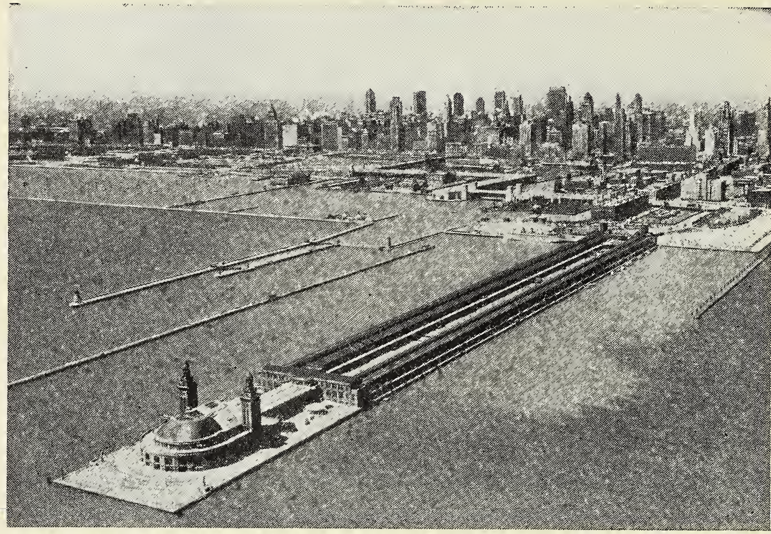


FIG. 5–4. Do you know why Chicago's position on Lake Michigan has helped the city to grow? (*Chicago Aerial Survey Co.*)

state of New Jersey. In addition to the states shown in the figure, entirely bounded by the waters of Lake Superior, there would be room for the state of Maryland. Lake Michigan, too, is as large as the combined areas of the states of Delaware, Maryland, and Massachusetts. [See Fig 5–4.]

From our lakes, rivers, and underground water we get our major supply of drinking water. Nearly all these areas are fresh water. A few of the inland waters, like the Dead Sea and Great Salt Lake, are salty and unfit to drink. Some of the underground water is salty, too, although most of it is fresh water.

88. **Where does underground water come from?** You have watched the rain falling heavily, and sometimes for hours. Did you ever ask yourself the question, "What happens to all the rain water that falls?" If you watch, you can see that much of it runs off to swell the brooks which carry it

to larger creeks. Then it flows into the rivers, or possibly into lakes, from which it may finally find its way to the ocean.

After the rain stops and the sun appears, some of the rain water *evaporates* and goes back into the air again. We cannot see this process taking place, because water vapor is invisible. We do know, however, that water left standing in an uncovered pan soon disappears. It must escape into the air in the form of particles too small to be seen by the naked eye. [See Fig. 5–5.] We know that water evaporates faster when it is heated. In fact, it is the heat from the sun that supplies the energy needed for the evaporation of water.

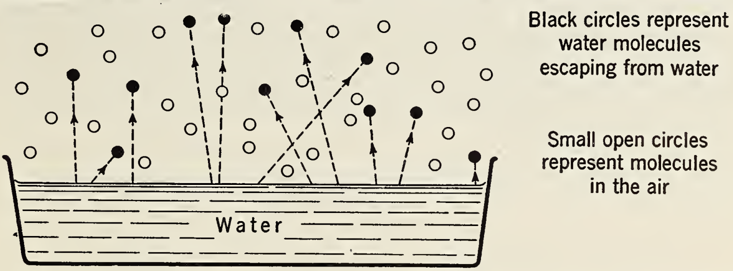


FIG. 5–5. Water molecules move toward the surface of the liquid and escape into the air. This is the way we may picture it.

But not all the rain water runs off, nor does it all evaporate. Some of it soaks into the soil and becomes what is known as *ground water*. If the rain falls *gently*, it does not run off so fast, and a larger portion of it sinks into the soil to form ground water. Do you think that more water will sink into a soil that is rather loose than into soil that is hard and closely packed? Will more or less of the water run off when the land is sloping? Do you think that grass, shrubbery, and dead leaves can help to hold water back and reduce the amount that runs away? By observation and study, we find that much of the water runs off if the soil is bare of vegetation, if it is closely packed, if the land is sloping, and if there is a

heavy downpour of rain. Cutting the forests on the slopes of the Appalachian Mountains has caused increased floods in the Ohio River valley. Can you explain why?

If we dig down into soil that seems fairly dry, we shall nearly always find water, provided we go deep enough. The level at which the water stands in the ground is called the *water table.* The depth of the water tables varies in different places and also in the same place at different seasons. In the spring the water table may be so near the surface of the ground that the water *seeps* through cellar walls.

Since plants need water, they must send their roots deep into the soil to obtain soil water, which comes from rains and moisture ascending from the water table. Alfalfa grows well in rather dry climates because it has long roots. When a person digs a well, he must make it deep enough to reach below the *permanent* water table, or his well will go dry in a long dry season. [See Fig. 5–6.]

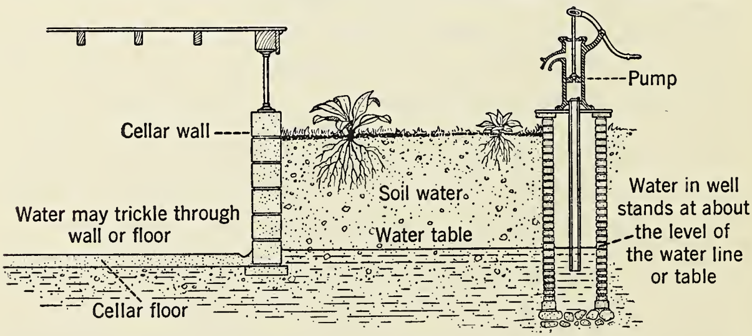


Fig. 5–6. The level of the water table varies at different times of the year.

Wells that have been dug show that there is a supply of water under the surface of the ground. What are some other proofs? Did you ever see a spring or a flowing well? Of course it would be impossible to have a fountain or a flowing

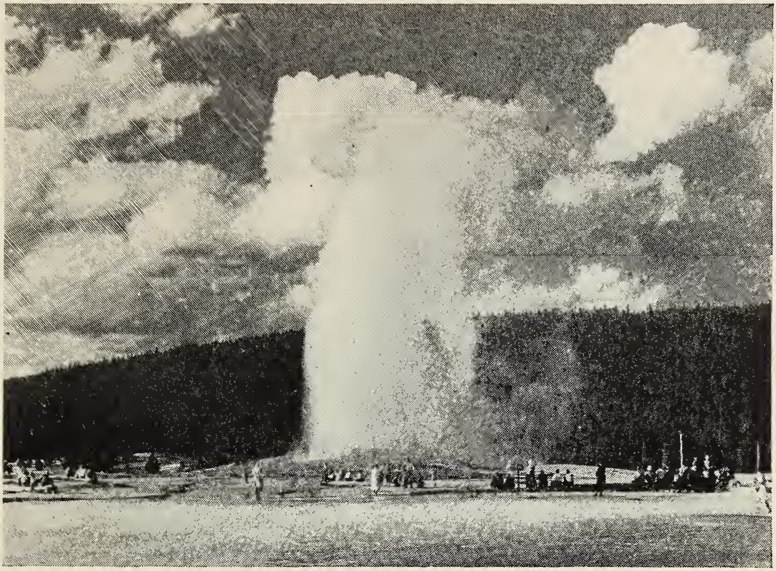


Fig. 5–7. Day after day, year after year, Old Faithful Geyser spouts out many gallons of boiling water. Eruptions occur regularly about an hour apart. That is how the geyser got its name, Old Faithful. (*Courtesy Yellowstone National Park*)

well if there were no underground water. Neither could we have any springs flowing from the ground. Another evidence of the presence of ground water is furnished by the *geysers* that abound in a few regions. Many geysers are found in Iceland, in New Zealand, and in our own Yellowstone National Park. At intervals they spout out large quantities of boiling water and steam, sometimes with so much force that the water is thrown to a height of from 200 to 300 feet. [See Fig. 5–7.]

89. What are some hidden sources of water? We have been studying some of the sources of water that are easily discovered or seen. Let us test some substances that seem dry, to learn whether they contain water. Let us weigh a head of Simpson lettuce and then place it on a steam radiator.

It soon wilts, and in a few days the leaves will become very dry. When we weigh it again, we shall find that it has lost a great deal of its weight. It would be possible to show that the loss of weight is due to the loss of water by evaporation. To show how much water was really lost, your instructor may pour enough water into a beaker to equal the weight lost by the head of lettuce.

In a similar manner, it is possible to show that such foods as meat, potatoes, tomatoes, bread, and milk all contain a large percentage of water. You could show by such an experiment that meats are about 50 per cent water, that potatoes are about 70 per cent, that milk is about 87 per cent, and that tomatoes are more than 90 per cent. Most of our vegetables lose at least 75 per cent of their weight when we heat them to drive off the water that is present in them.

The sap in plants and trees is composed largely of water. For that reason plants do not thrive unless there is an abundant supply of water in the soil. Then the roots can push down into the soil and take up the water which later finds its way to all parts of the plant.

It is estimated that a man who weighs 140 pounds is composed of 100 pounds of water by weight. Since a quart of water weighs about two pounds, 100 pounds of water will fill fifty quarts, or twelve and one half gallons. [See Fig. 5–8.] That amount of water poured into a bath tub is enough for a generous bath. Of course our blood is largely water. Our nerves are particularly watery, and our muscles are more than 60 per cent water. Since our bodies lose water through the skin, the lungs, and the kidneys, it is not difficult to understand why *an adult person needs at least six glasses of water every day.*

At all times the air contains water in the form of invisible *vapor.* Even in desert regions the air is not completely dry.

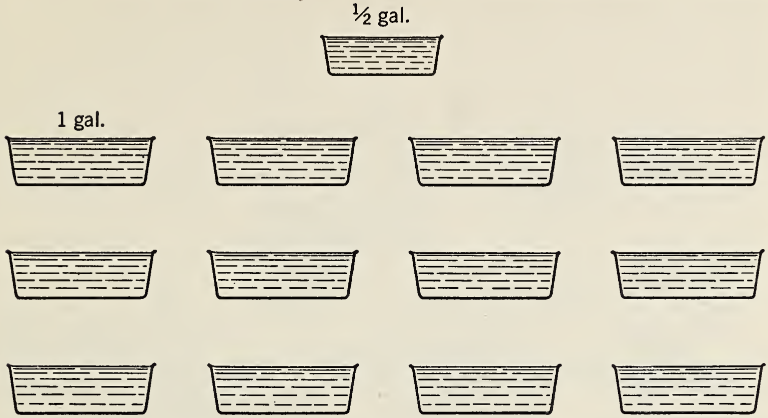


FIG. 5–8. A man who weighs 140 pounds contains about 100 pounds of water – more than enough to drown him.

Warm air can hold more moisture than cold air. That explains why air may lose some of its moisture in the form of dew, rain, or snow if it is chilled sufficiently. How do you think that nearness to a large body of water affects the amount of moisture that there would be in the air? Do you think it makes any difference in the amount of moisture in the air whether the wind blows from the land toward the water or from the water toward the land?

90. **How is water used?** For centuries men have used the ocean for transportation and commerce. Canals and rivers, too, afford cheaper transportation than railroads and trucks. Some of you may have seen models of the vessels used by Columbus. [See Fig. 5–9.] They look very small when compared with the giant superliners that are in use today. From such small sailing vessels to the *Normandie*, the *Queen Mary*, and the *Queen Elizabeth* is a tremendous stride in progress. The *Queen Mary* is 1,018 feet in length and 118 feet wide. Three football fields placed end to end would not be so long as the *Queen Mary*, and her width is almost equal

FIG. 5–9. Would you want to start across the Atlantic Ocean in such small, frail-looking boats as those Columbus sailed?

to the distance from the home plate of a baseball diamond to second base. It would require forty miles of freight cars to carry all the material used in building such a vessel, and yet she may be tossed about by the huge waves of the stormy Atlantic Ocean. [See Fig. 5–10.]

Many men find employment in taking valuable products from the sea. Not long ago the demand for sealskin became so great that strict laws had to be adopted to protect the fur-bearing seal and prevent its extermination. New Bedford, Massachusetts, was at one time the center of a thriving whaling industry. Whale oil and blubber were valuable products. The demand at present is not so great, but laws are necessary to protect the whale, and save it from extinction.

The catch of salmon, cod, halibut, flounder, haddock, bluefish, sardines, herring, and many other food fishes is worth millions of dollars annually. The work furnishes employment, too, for many men. Other valuable food products coming from the sea include crabs, lobsters, clams, and oysters. The pearl fisheries are important industries. Sponges are the cleaned and dried skeletons of animals that are found in warm ocean waters, particularly along the Florida coast. Many sponges are secured at such places as Tarpon Springs, Florida.

In some places seaweeds are dragged ashore and burned. From the ashes two valuable products are obtained. One of them is *iodine,* which is dissolved in alcohol for use as an antiseptic. The other one is *potash,* which finds use as a plant fertilizer. Within the past few years an industrial chemical plant was built in North Carolina for the purpose of taking *bromine* (brō′mēn) from sea water. It is now in successful operation. Considerable bromine is used in making a product which is added to gasoline to make automobile engines run more smoothly. There is a considerable amount

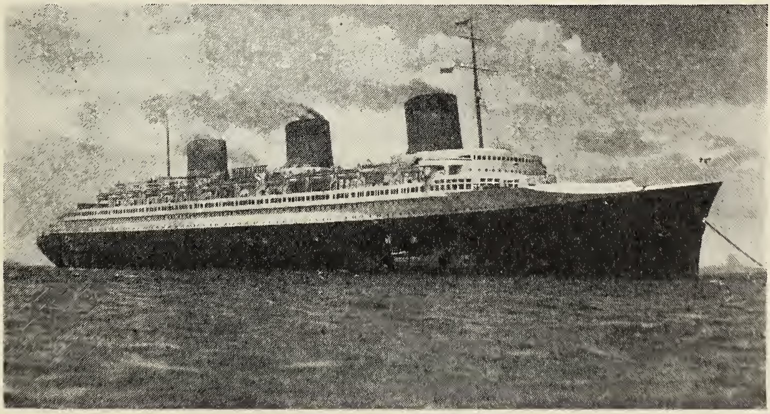


Fig. 5–10. Have you ever been aboard a modern ocean liner? In many ways such ships as the *Normandie* resemble huge floating hotels.

of gold in the waters of the ocean, and chemists still dream of getting it from the water at a profit. You may live to see this hope realized, or it may be your good fortune to accomplish the task yourself.

Water warms slowly and it cools slowly. It plays an important part in keeping the surrounding air cool in summer and warm in winter. A large body of water causes places that are near it to have a more temperate climate. The fruit trees along the shores of Lake Ontario, for example, do not bloom so early in the spring as those some distance from the lake, and the flowers are therefore not so likely to be ruined by a late frost in the spring. Then, too, there is less danger of an early frost in the fall, which would do great damage to the fruit.

Without large bodies of water there could be no rainfall. The oceans serve as huge reservoirs from which moisture is constantly escaping into the air in the form of water vapor. The winds carry the water vapor to the land areas. When the air is cooled, rain may fall.

91. What creatures live in the water? From the preceding section, we conclude that water is a home for fish, shellfish, sponges, whales, and such fur bearers as the seal and walrus. Many other animals make the sea their home. Some of them are so tiny that we must have a microscope if we wish to see them. The ocean also teems with shipworms, barnacles, crabs, starfish, jellyfish, and hundreds of other animals. [See Fig. 5–11.]

Some other animals make the water their home only a part of the time. Among them we find the muskrat, the otter, and the beaver. These animals prefer fresh water. The toad and the frog lay their eggs in the water, and their young live in the water as tadpoles during the early part of their lives.

FIG. 5–11. Some kinds of animal life, such as these fur-bearing seals, grow abundantly in the cold Arctic Zone. (*Courtesy U. S. Department of the Interior*)

92. Why did men build cities where we now find them? If you look at a map of the world, you will find many large cities situated on the shores of oceans. You will find cities where there are excellent harbors, too. The harbors must be large enough to permit ships to move freely. They must be deep enough so that large ships will not touch bottom and run aground; and they must be landlocked so that the ships will be protected against waves and excessive tides. In many cases the cities are at, or near, the mouth of a river, or on some bay, sound, or other arm of the ocean.

If we look at the map, we find that the following cities are well situated for carrying on commerce: Quebec, Boston, New York, Baltimore, Philadelphia, New Orleans, San Francisco, Seattle, Yokohama, Shanghai, Melbourne, Buenos Aires, Rio de Janeiro, Naples, London, and Rotterdam. No doubt you can find many others.

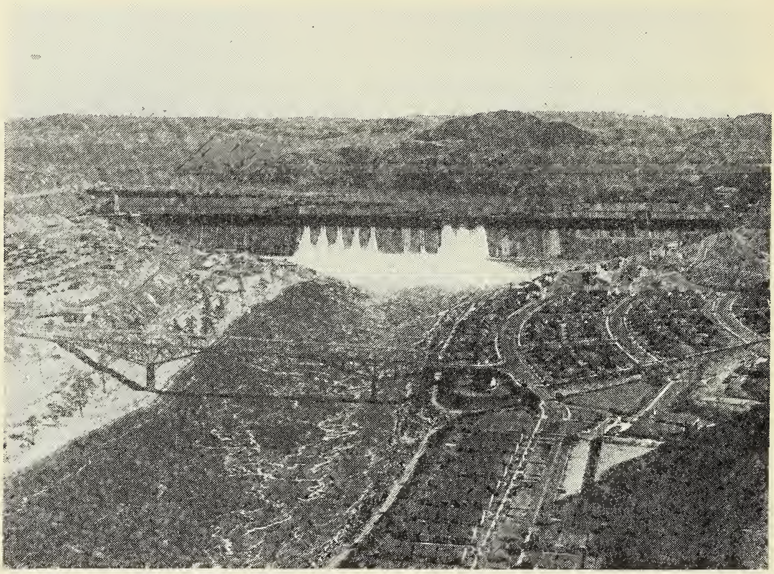


Fig. 5–12. Man builds huge dams to enable him to use water to make electricity. The base of Grand Coulee Dam covers almost fifty acres. (*Courtesy U. S. Department of the Interior*)

Some other cities are located farther from the mouths of the rivers. They are at the head of navigation, or as far up the river as large boats can go; this place is usually the *fall line* of a river. Many cities depend not only upon such commerce, but also upon the power which can be obtained from swiftly running water or from falling water. The silk mills of Paterson, New Jersey, get power from the falls of the Passaic River. The cities of Minneapolis and St. Paul get water power from the Falls of St. Anthony, in the Mississippi River, to run their huge flour mills. Can you find some other cities that are at the fall line of a river?

Questions

1. Explain why the old lady who thought that some of the ocean should have been farm land was not very wise.

2. Why does the depth to which a well must be dug depend upon the depth of the water table?

3. Do you know of any springs which flow only during certain seasons of the year? Can you explain why such a thing may be possible?

4. Under what conditions does rain water run off the land very slowly?

5. Why does hot water evaporate faster than cold water does?

6. From your own observations, do you find that alcohol evaporates faster than water does?

7. Why do some wells go dry in summer or fall?

8. How has the removal of the forests in the Appalachian Mountains of Pennsylvania affected flood conditions in the Ohio River Valley?

Some things for you to do

1. Pour about one pint of milk into a pan and weigh it. Let the pan stand on the radiator until the liquid part of the milk has evaporated. Then weigh it again. How much weight did it lose? What per cent of its weight did it lose?

2. Place three or four dry beans in a large test tube. Heat the test tube for a few minutes, taking care not to let it get hot enough to scorch the beans. What do you find collecting on the cooler, upper part of the test tube?

Think about these!

1. A pan of water has been permitted to stand for several days. You find that the water has disappeared. Where has it gone? Is it possible to get it back again?

2. Why do water pipes sometimes burst when the water in them freezes?

3. How do fish breathe under water?

Words for this chapter

Condensation (kŏn′dĕn·sā̤′shŭn). The process in which a vapor is changed to a liquid.

Theory. A reasonable explanation of some natural happening. A theory is an idea which has not yet been, or cannot be, entirely proved by experiment in a laboratory.

Molecule (mŏl′ė·kūl). The smallest particle into which matter can be divided without losing its identity.

Hydrogen (hī′drō̇·jĕn). A gas, the lightest substance known.

Vacuum. A space that does not contain any matter, not even air.

Volume. The amount of space occupied.

Carburetor (kär′bū̇·rĕt′ẽr). An apparatus used to change liquid gasoline into gasoline vapor and to mix it with air.

Properties. The qualities or characteristics of some particular substance.

Mineral. Any fairly pure substance, not a direct product of a plant or an animal, found in the rocks of the earth.

Force. Muscular effort; or something that produces the same effect.

Solution. A liquid in which some substance has been dissolved.

Ignite (ĭg·nīt′). To take fire.

Explosion. Oxidation which occurs almost instantaneously.

CHAPTER 6 ______________ UNIT 3

What Can Water Do?

93. In what three forms can water exist? The King of Siam lived all his life in the tropics. Some travelers from the northern part of Asia paid him a visit. The King did not believe them when they told him that water sometimes becomes solid enough in northern Asia to bear up the King's elephants. Many persons who live in the Tropics have never seen snow and ice. [See Fig. 6–1.] Those of us who live in the Temperate Zones know that water will freeze, or change from the liquid state to the solid state, if enough heat is *subtracted* from the water. Taking heat from a substance cools it, or lowers its temperature.

Suppose we let a pan of water stand for a few days in a warm room. The water soon disappears. If a second pan of water is placed on the top of a hot radiator, the water in that pan disappears *more rapidly*. If we *add* heat to liquid water, some of the water particles escape into the air in the form of a *gas*, or a *vapor*. We call the process *evaporation*. The tiny particles are so small that we cannot see them as they

Fig. 6–1. Boys who live in Panama or Ecuador do not have much chance to play ice hockey. (*Ewing Galloway*)

escape. Even if we examine the air with the best microscope that was ever made, we cannot find any water particles at all. Yet we know that they are there. We may prove it by letting a glass of ice water stand in a warm, moist room. Soon tiny drops of water condense on the outside of the glass. Cooling the air condenses some of the water vapor, changing it back again from the gaseous state to the liquid state. We call such a process of changing from a vapor to a liquid, *condensation.* You will hear more about it later.

94. How are theories built? We are *certain* that water evaporates, but we cannot see the operation taking place. Scientists have formed a *theory* to explain the process. They are firmly convinced that all matter is made up of extremely small particles called *molecules.* A molecule of water is believed to be the smallest particle of water that can exist. If the water molecule is broken up, as may be done by a chemist, we no longer have water, but two gases called *hydrogen* and *oxygen.* A molecule of common table salt is the

smallest particle that we can have if we are still to have salt. If we split up such a molecule, we have a soft, silver-white metal, and a greenish-yellow gas.

No microscope is powerful enough to enable us to see molecules. If we could see them, then we would no longer speak of the *molecular theory,* but we would call it one of the *natural laws.* It is estimated that at least 1000 molecules placed side by side would be required to make a line long enough to be seen by the best microscope. Of course gases are composed of molecules too, according to the molecular theory.

We breathe from sixteen to eighteen times per minute. It is estimated that in every breath of air we inhale there are about 13,000 million-million-million molecules. Let us use another estimate. An ordinary radio tube is a *vacuum* tube. If we could punch in it a hole so tiny that only one million molecules of air could enter the radio tube per second, it would require about 90,000,000 years to fill the tube with air. Scientists are almost as certain that molecules exist as if they could actually see them.

95. What is evaporation? We believe that matter is made up of molecules. It seems certain, too, that the molecules are usually moving rapidly. Imagine a pan of water in a warm room. [See Fig. 6–2.] The molecules in the pan of water are moving in all directions. Those inside the liquid

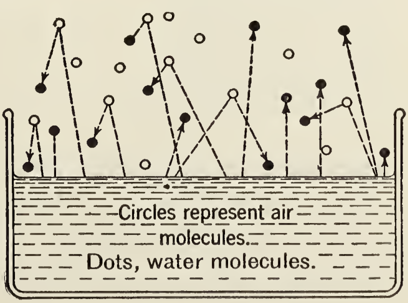


Fig. 6–2. Air molecules retard evaporation. They get in the way of the water molecules which are trying to escape from the surface of the water.

cannot move very far because they bump against other molecules and are stopped. These molecules bump into other molecules in turn and throw them into motion. But, suppose we think only of those molecules of liquid that are moving upward at the water surface. Some of them escape into the space between the air molecules, and mix with the air. Some of them strike some of the air molecules and rebound to the surface again, just as a rubber ball rebounds after it collides with a hard surface.

The molecules move more rapidly when the temperature is increased. Of course, the more-rapidly-moving molecules escape from the surface faster. For that reason the warming of water makes it evaporate more rapidly. To summarize, we may say: (*a*) matter is made up of tiny molecules; (*b*) molecules of matter are in rapid motion; (*c*) increasing the temperature makes the molecules move more rapidly. These three statements briefly outline the *molecular* (mō̇·lĕk′ū̇·lẽr) *theory of matter*. [See Fig. 6–3.]

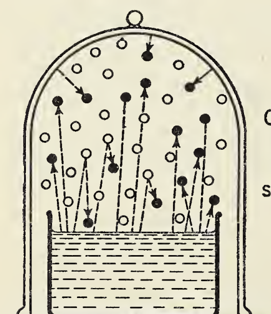


FIG. 6–3. Let us suppose that a million molecules escape into the air every second, and that a million hit other molecules and rebound to the water every second. Then the air will be saturated with water vapor.

96. **How do solids, liquids, and gases differ?** Let us examine a *solid* substance, a brick, for example. We find that its *size or volume is definite*. It may be six inches long, four inches wide, and two inches thick. Tomorrow we may ex-

pect to find that it is the same size, except for a slight expansion which might occur if the temperature has increased. If we place the brick on the table, it keeps its *shape* and does not spread out all over the table. *Most solids have a definite size and a definite shape.*

If you try to pour a quart of milk into a pint bottle, you will fail. The quart of milk, like the brick, has a *definite size or volume.* If you pour the milk into a broad pan, the milk spreads out and takes the shape of the pan. If it is poured into a round bottle, it takes the shape of the bottle. If it is poured out on a table top, it spreads all over the table. The shape of the liquid is *not* definite. *Liquids have a definite size, but they take the shape of their container.*

A small amount of gas placed in a vacuum bulb expands and fills the entire bulb. It takes the shape of the bulb, too. If we pump enough air into an automobile tire, the air, which is a mixture of gases, fills the tire, no matter what its shape or size. *Gases have neither a definite size nor a definite shape.* They take the shape of their container; they expand until they fill their container.

97. How does a change in temperature affect matter? We have learned that water may be changed into a vapor or a gas when heat is *added* to it, and that it may be changed into ice when enough heat is *subtracted* from it. Do other substances behave in a similar manner? The *carburetor* of a gas engine changes liquid gasoline into gasoline vapor and mixes the vapor with air. It is possible, also, to freeze gasoline if it is cooled to a very low temperature. It is possible to heat iron hot enough to melt it, or even to boil it and change it into gaseous iron. Mercury, too, can be frozen into a rigid solid, or it may be changed into a gas. It is possible, too, to have copper, lead, zinc, and tin melted by heating, or even changed into a vapor if they are heated strongly enough.

98. What are some of the properties of water? One of the *properties* of pure water is that it has no odor, color, or taste. In deep layers, pure water appears blue on a sunshiny day. Nearer the shore, sea water may appear purple and even green. Millions of tiny animals or plants present in the ocean sometimes give sea water a green color. This is particularly true when the water is shallow. Certain microscopic plants growing in fresh water may give it a fishy taste though the water is all right to drink. Decaying animal or vegetable matter or sewage may give water a bad odor and a bad flavor. Such water may be dangerous to drink. Sometimes *mineral* matter dissolved in water may also give it a distinct flavor.

We know that water will dissolve substances such as sugar and salt. Many other liquids will dissolve substances. Gasoline or ether will dissolve oil or grease. The drugs which are extracted from certain plants for use in medicine will not easily dissolve in water, but they do dissolve in alcohol. Therefore we conclude that some substances dissolve readily in one liquid, but not in another. Water dissolves more different things than any other known liquid.

Water freezes at a temperature of 32° on the *Fahrenheit* (făr′ĕn·hīt) scale. The Fahrenheit thermometer is used in England and in the United States to measure temperatures relating to weather conditions. It is also used in many factories and for various other purposes. In a later chapter we shall study a thermometer which is graduated (marked off into degrees) differently from the Fahrenheit thermometer.

At sea level, pure water boils at a temperature of 212° Fahrenheit. At the city of Denver, which is about one mile above sea level, water boils at about 200° Fahrenheit. At Quito, Ecuador, which is about 9000 feet above sea level, water boils at from 190° to 195° Fahrenheit. At high alti-

tudes the boiling point of water is lower than it is at sea level. It takes less heat to warm water to the boiling point in the cities just named, but the boiling water is not so hot as the boiling water which we are accustomed to see. Vegetables will cook very slowly in such boiling water, and it is difficult to hard-boil eggs. [See Fig. 6–4].

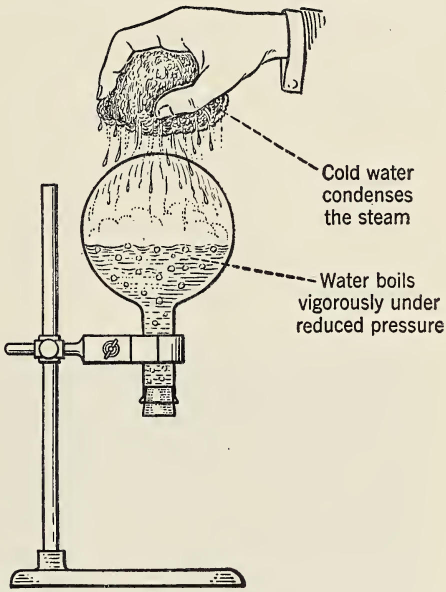


FIG. 6–4. Lowering the pressure lowers the boiling point. If a boy wishes to make good time in running the 100-yard dash, he does not select a busy street where he will find many persons in his way. He goes to a place where he will not be hindered. In a similar way, removing the air above the water surface permits the water to boil more rapidly.

99. How does the volume of water change as it freezes? Have you ever seen a bottle of milk that looked like the one in Figure 6–5? Possibly you will recall that milk is about 87 per cent water. You can see in such a case that the volume of the water increased as it froze and pushed the cap up out of the bottle. Some of the contents of the bottle, too, are pushed upward. It can be shown by experiment that ice takes up about 1.1 times as much room as the water did from which the ice was formed. Sometimes such expansion by freezing bursts the milk bottle.

Fig. 6–5. Water increases in volume as it freezes. The expansion of the freezing water pushes the cap up out of the bottle. It may cause the bottle to burst, because freezing water can exert enough pressure even to split apart huge boulders.

100. How does the expansion of freezing water affect us? If the water freezes in the pipes of your home in winter, the pipes are likely to burst. The *force* which the freezing water exerts as it expands in the pipes is tremendous. Water is used to cool the engine of your father's automobile. It circulates around the engine and through the radiator. In the winter time it may freeze and crack the radiator or the water jacket which surrounds the engine cylinders. To prevent such loss or injury, an antifreeze *solution,* prepared by adding alcohol, glycerine, or some other chemical to water, is used to fill the radiator and other parts of the cooling system, when winter approaches. Solutions for this purpose can be made which will not freeze until the temperature falls to many degrees below zero.

Possibly you have seen concrete walks that were lifted by the expansion of the water as it froze beneath the walks. Roads, too, may be badly damaged when the water gets under them or between rock particles, and then freezes. If the foundation walls of buildings do not extend below the frost line, they may be lifted by the expansion of the freezing water. Green plants that normally live through the winter are sometimes killed by being lifted with the soil as the water

in the soil freezes. When a thaw comes, the soil settles and leaves many roots of the plants exposed above the ground. Alternate freezing and thawing are injurious to such plants as grass, clover, and winter wheat.

101. What are the properties of water vapor? When water boils in a glass flask, we cannot see the vapor or steam above the boiling water. Steam and water vapor are invisible. What we do see and usually call steam as it comes from the spout of a teakettle, really consists of tiny drops of water that are formed when the steam condenses as it touches the colder air surrounding the spout. These drops appear as a white cloud. Water vapor is not only colorless, but it is a light gas, not so dense even as dry air.

Have you ever wondered how a few gallons of water put into the boiler of a steam-heating furnace can possibly fill all

Fig. 6–6. As a boy, James Watt was curious about the steam which lifted the lid of a teakettle. How has his curiosity helped you?

the pipes and radiators all over the house with steam? Water expands to some extent when it changes to ice, but one gallon of water, when it is boiled away, expands as it evaporates and forms about 1,700 gallons of steam.

What happens if we heat water strongly in a covered vessel from which the steam cannot escape? The vessel may burst or explode, because there is no outlet for the expanding steam. You have heard the story of James Watt, who, as a boy, became interested in the force of expanding steam, while he watched the teakettle lid jump upward when the water in the kettle boiled. From that simple observation, Watt got the idea of using the force from expanding steam for making a steam engine. [See Fig. 6–6.]

102. What is a solution? Let us add a few crystals of common table salt to a cup of water and stir it gently. The crystals soon disappear. We say they dissolved in the water and formed a solution of salt in water. The water is called the *solvent* (sŏl′vĕnt), and the salt in the solution is called the *solute* (sōl′ūt). One drop of the solution taken from the top of the cup will taste as salty as a drop taken from the bottom of the cup or from the middle. This proves to us that the mixture of salt and water which we call a solution has the same nature throughout.

Let us put some of the salt solution into a bottle, stopper it tightly, and permit it to stand in a room for several days or weeks. If the temperature of the room does not change, the salt does not separate from the solvent, no matter how long it stands. If the conditions are not changed, a solution is permanent.

103. How can you experiment with solutions? In learning that solutions are the same throughout and are permanent, we used examples to suggest the scientific method of study. We may carry the experiments further. Fill each of

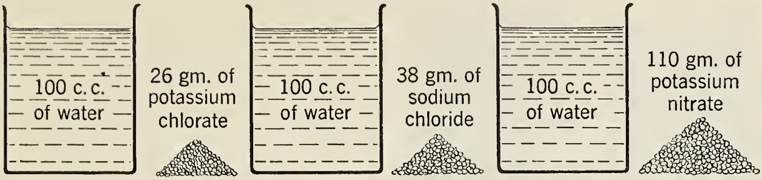


FIG. 6–7. Some substances are much more soluble in water than others. The figures show the amount of each substance that dissolves.

the beakers nearly full of water, as in Figure 6–7. To one of the beakers let us add a level teaspoonful of *potassium chlorate;* to a second beaker let us add an equal amount of *sodium chloride;* and to the third let us add an equal amount of *potassium nitrate.* Do some of the crystals seem to dissolve faster than others? How does stirring the water and crystals with a glass rod affect the rate at which they dissolve? Suppose you continue to add more crystals to each beaker, stirring after each addition, until no more will dissolve. If you have done your work well, you will have found that some substances dissolve faster than others, and that the total amount that will dissolve varies with the kind of crystals used.

To a beaker half full of cold water, add a lump of sugar. To a beaker half full of hot water, add a lump of sugar. Stir each one. Which dissolves more quickly? Continue to add sugar to each one until no more will dissolve. Do you find that you can dissolve a greater amount of sugar in a given amount of *cold* water or in the same amount of *hot* water? In a similar manner, you can find out for yourself whether large crystals or small crystals dissolve more rapidly.

Suppose you let one end of a string hang in the hot sugar solution while the solution cools. Some of the sugar is finally deposited on the string in the form of crystals. Rock candy is made in this way. [See Fig. 6–8.]

FIG. 6–8. Do you know how to make rock candy? Lower a string into a hot, saturated solution of sugar and water. Let the string remain hanging in the solution for several days. The sugar will slowly separate from the solution and form a mass of crystals on the string. If you are patient, you will soon have some rock candy to eat. (*Photo by W. R. Bennett*)

104. Can we dissolve gases in water? By experiment it can be shown that several gases are soluble in water. Fish get the oxygen they need from the air dissolved in water. As the water flows over the gills of the fish, the oxygen passes through the gills into the blood of the fish. Most solids dissolve more rapidly and in greater quantity in hot water than in cold water, but the reverse is true of gases. Gases dissolve less readily in hot water than they do in cold water. Suppose we let a glass of cold water stand in a warm room. Bubbles of air come out of the solution as the water grows warm, and they adhere to the inside of the glass. The milky appearance which water sometimes has when it is drawn from the hot-water tap, is due in part to bubbles of air which are driven out of the water when it is heated.

105. How does sea water differ from fresh water? Rain water is known as *fresh* water. It does not contain any mineral matter dissolved in it. As rain water trickles through the soil, or runs over the soil and rocks, it slowly dissolves some salt and other soluble minerals that may be present in the soil or the rocks. Such dissolved matter is carried with the water as it makes its way toward the ocean.

As the water evaporates, the mineral matter does not evaporate with it, but is left behind, dissolved in the waters of the sea. During all the years that evaporation of water and condensation of water vapor have been taking place, mineral matter has been carried into the oceans. Thus the sea water has gradually become more and more salty. Some other substances besides common table salt are carried into the ocean. Sea water contains compounds of *calcium* (kăl′sĭ·ŭm), *magnesium chloride* (măg·nē′shĭ·ŭm klō′rīd), and small quantities of many other minerals or salts. These substances make the sea water salty, bitter, and entirely unfit to drink.

106. What is a cycle? The word *cycle* (sī′k'l) comes from a Greek word which means *ring* or *circle*. Our words *bicycle* and *motorcycle* come from the same Greek word. It applies especially to something that occurs at one time and then recurs at a later time, or to something which occurs, then reverses, only to be followed by the same procedure. A farmer, for example, may plant a field to wheat one year, to clover the next, to corn the next, and to oats the following year. If he then repeats, using the same order for another four years, he is rotating his crops in a *definite cycle*. In a gasoline engine the gasoline vapor and air first enter the cylinder; they are then compressed; they then *ignite* from a spark from the spark plug in order to form an *explosion;* finally the waste products are forced out of the cylinder. The operation then begins all over again. We speak of such an engine as a *four-cycle* engine, although it may be better to call it a *four-stroke* engine.

107. What is the first step in the water cycle? The woman who was mentioned in Chapter 5 as thinking the oceans were too large, did not know very much about the importance of the water cycle. Let us consider evaporation

as the first step in the water cycle. A quart of water will evaporate more rapidly if poured into a broad pan than it will from an ordinary milk bottle. It has more surface from which the rapidly moving molecules can escape. The broad expanse of the ocean affords a very large surface area from which water is always evaporating. Millions and millions of tons of water escape into the air every day from the oceans, the lakes, and the rivers. Since water vapor is less dense than dry air, it may be pushed upward by the denser air surrounding it, and it may rise to a height of a few miles.

108. How is cloud formation the next step in the water cycle? Probably you have already learned that the air at high altitudes is colder than it is at, or near, the earth's surface. As the water vapor is pushed upward into the colder

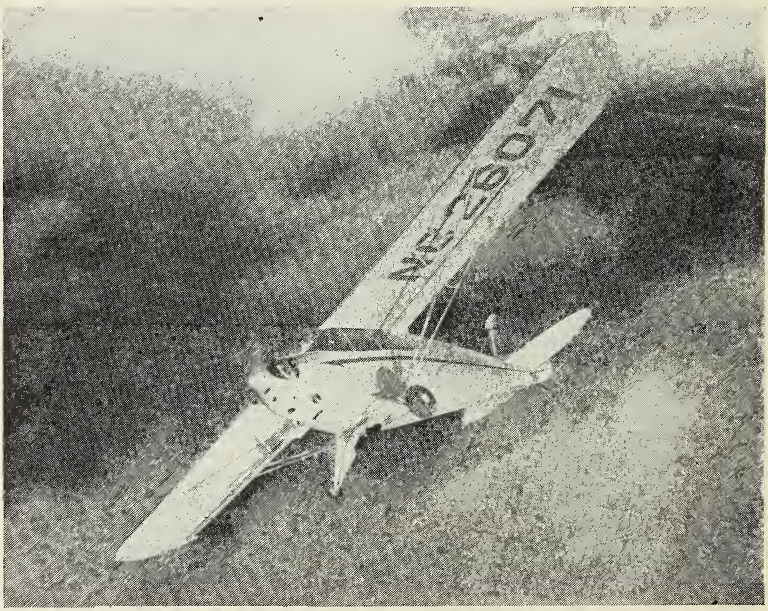


Fig. 6–9. The airplane passes through the clouds in its flight just as an automobile can pass through fog or mist. (*Groenhoff photo, courtesy Piper Aircraft Corp.*)

Fig. 6–10. Cirrus clouds are light and fleecy. (*Courtesy U. S. Weather Bureau*)

portions of the air, it loses heat; its molecules then move more slowly, and some of the vapor condenses into tiny drops of water. These tiny drops often stay afloat in the air and form clouds. [See Fig. 6–9.]

There is little difference between a cloud and a fog. As we have seen, the cloud is formed by water condensing into tiny drops, usually *some distance above* the earth's surface. A fog is formed by condensing the water vapor into drops *near the surface* of the earth when the air becomes chilled rather suddenly. A cloud usually has a more definite shape.

Sometimes light, fleecy clouds are formed so high up that the temperature of the air at that elevation is below the freezing point. Then the water vapor in the clouds condenses and freezes into snow or frost particles. [See Fig. 6–10.] The *cirrus* (sĭr′ŭs) clouds shown in this figure may be at an alti-

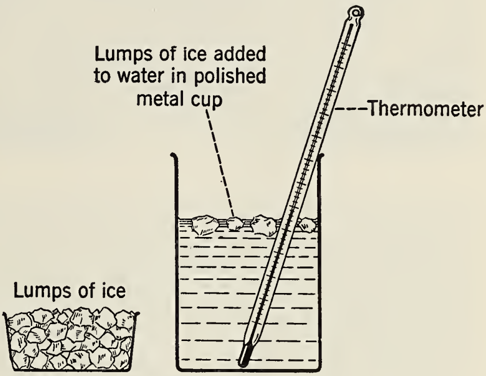
FIG. 6–11. Cumulus clouds may form dark thunderheads, or nimbus clouds, from which rain falls. (*Courtesy U. S. Weather Bureau*)

tude of from three to five miles. The thunderheads which are so common in the late afternoon following a hot day in summer are formed at an elevation of from 2000 to 3000 feet. Figure 6–11 shows *cumulo-nimbus* (kū′mū̇·lō nĭm′bŭs) clouds that are common in summer.

109. What part do winds play? If you lie and watch the clouds, you see them drift along, carried by the winds. Sometimes they move in a direction opposite to that in which the wind is blowing at the earth's surface. This proves that the winds in the upper air do not always blow in the same direction as they do at the surface. From the oceans, the winds carry water vapor and clouds long distances inland. Thus it is easy to see that we are largely dependent upon the oceans to furnish the moisture for the clouds which bring us the rain. Without the oceans, most of the land areas would soon be nothing but desert regions.

110. What is the last step in the water cycle? Let us fill a polished metal cup half full of water. If we add ice to the water, a small lump at a time, and stir the mixture of ice and water with a thermometer, we can cool the water and the metal cup enough to cause tiny drops of water to condense on the outside of the shiny surface. As soon as a film of moisture appears, we should read the thermometer. Thus we find the temperature to which the air must be cooled in order to have the moisture of the air condense. *That temperature is called the dew point.* [See Fig. 6–12.] This experiment also

FIG. 6–12. The water may be cooled until dew forms on the outside of the cup. If the water is cooled below its natural freezing point by adding some salt, too, then frost forms on the cup.



serves to convince us that warm air can hold more moisture than cold air. Warm air takes up moisture much as a sponge does. If we squeeze a wet sponge, water drips from it. If we cool air which is warm and moist, the moisture condenses in drops.

In exactly the same manner that moisture collected on the metal cup when it was sufficiently cooled, so *dew is deposited* on walks, grass, and other objects when they cool off at night and chill the air which surrounds them. If the dew point is below 32° Fahrenheit, then *frost is formed* as the moisture condenses. It is incorrect to say that either dew or frost

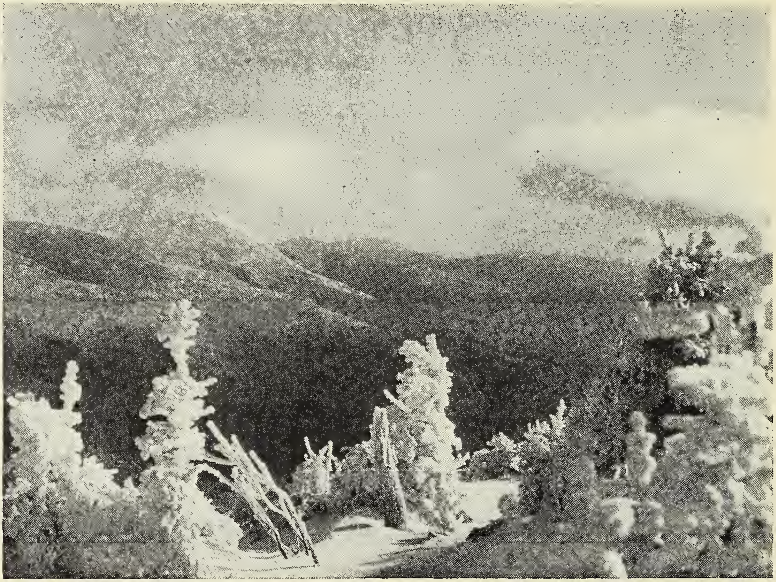


FIG. 6–13. As the frost forms on the shrubbery, it changes the place into a fairyland. (*Photo by U. S. Forest Service*)

falls. [See Fig. 6–13.] Chilling masses of air near the surface of the earth may cause the moisture to condense and form *mist* or *fog.*

Suppose we have large volumes of warm air which is very *humid,* or moist. Possibly these air masses are nearly *saturated,* or soaked, with moisture, or else they hold nearly all the moisture it is possible for them to hold even at a *high* temperature. What will happen if a cold wind, from the north for example, blows in and mixes with the warm, moist air? It seems likely that the whole mass of air will be cooled below its dew point. The moisture will probably condense into drops which are large enough to fall to the earth as *rain.* [See Fig. 6–14.] Any cloud from which rain falls is called a *nimbus* cloud, or a rain cloud. We speak of the falling rain as *precipitation.* This long word comes from the Latin. It

means *falling headlong* or *being thrown down.* If the temperature of the air is below the freezing point of water, then the precipitation occurs as sleet or snow. Rain water soaks into the ground, but the excess runs off into streams, rivers, or lakes. Eventually it finds its way back to the ocean. This completes the water cycle. Then the process starts all over again. Water is present in all stages of this cycle. We may summarize the water cycle as follows: (*a*) evaporation of water takes place; (*b*) the water vapor in the air condenses to form clouds; (*c*) the winds carry the clouds and water vapor from place to place; (*d*) the masses of moist air are cooled; (*e*) precipitation in some form occurs; (*f*) the rain water returns again to the bodies of water such as the ocean.

111. How is the air cooled? There are several ways in which moist air may be cooled to form precipitation. (*a*)

FIG. 6–14. A cloud from which rain falls is a nimbus cloud. (*Courtesy U. S. Weather Bureau*)

Warm, moist air is less dense than cold air. Hence warm, moist air may be pushed upward by the colder, heavier air around it until it reaches an altitude where it is cooled enough to condense the moisture and cause rain. At, or near, the equator the hot sun heats the air strongly. The air is pushed upward, becomes cooled, and its moisture falls as rain. Since this happens nearly every day, places near the equator lie in the *zone of daily afternoon rains.* (*b*) A cloud laden with moisture may be carried upward over a mountain range. In passing over the mountain, it may be cooled enough to cause rain or some other form of precipitation. The western slopes of the Rocky Mountains have plenty of rain for this reason. As the air creeps downward on the eastern slopes of these mountains, the air is being warmed. *Rain can never come from air that is being warmed.* The eastern slopes of the Rockies and the Great Plains to the eastward have very little rainfall. (*c*) Sometimes cold winds blow in and mingle with warm, moist air. Then precipitation may occur. (*d*) In winter, the land is colder than the adjacent ocean. Winds blowing from the ocean toward the land may be cooled enough to cause rain. Los Angeles, for example, may have rain in winter, but it seldom rains there in summer, because at that time the land is warmer than the moist air coming in from the Pacific Ocean.

Questions

1. Is it possible to melt iron? Can iron exist as a gas or vapor?
2. Why do the western slopes of the Rocky Mountains have more rainfall than do the eastern slopes?
3. Why does Los Angeles have more rain in winter than it does in summer?
4. What is meant by the water cycle?

5. How does sea water differ from fresh water? Which one will freeze at the lower temperature?

6. Does it take more or less heat to warm a quart of ice water to the boiling point at Denver than it does in New York City? Explain.

7. Can potatoes be cooked more quickly by boiling them at San Francisco or at Quito, Ecuador?

8. Alcohol is sometimes added to automobile radiators in winter. What can you tell, therefore, about the relative freezing points of water and alcohol?

9. What are some of the properties of a solution? Is water ever used as a solvent?

10. Are gases more soluble in hot water or in cold water?

11. Will a lump of sugar dissolve more quickly in a glass of iced tea or in a cup of hot tea?

12. Mention three substances which will dissolve in alcohol, but not in water.

Some things for you to do

1. Make a large enough hole in a piece of "dry ice" to permit the lower end of a test tube to stand in it. Be careful not to handle "dry ice" with unprotected fingers. Add to the test tube a few drops of mercury. Let it stand several minutes. Does the mercury freeze? Repeat the experiment, using some water in the test tube. Does the water freeze quickly? Can you freeze alcohol in the same manner?

2. Try to dissolve a piece of chewing gum in carbon tetrachloride. Suggest a use for carbon tetrachloride.

3. Crush a green leaf and add it to a small beaker containing alcohol. Does the green coloring matter from the leaf dissolve in alcohol?

4. Make a hot, saturated solution of granulated sugar. Suspend a string in the solution and let it stand for a day or more. What do you observe? Can you explain this action?

Think about these!

1. Which do you think is denser (some persons incorrectly say *heavier*), moist air or dry air? Have you a good reason for your opinion?

2. In the fall why is the water in a lake likely to be warmer than the surrounding air especially at night?

3. How does the Gulf Stream affect the climate of England?

Words for this chapter

Element. A substance which is not split up into simpler substances by chemical change.

Conductor. A substance through which heat or electricity can pass easily.

Atom. The smallest particle of matter with which the chemist deals in chemical changes.

Meter (from the Latin *metrum,* measure). The unit of length in the metric system. A meter equals 39.37 inches.

Gram. The unit of weight in the metric system. There are 454 grams in one pound.

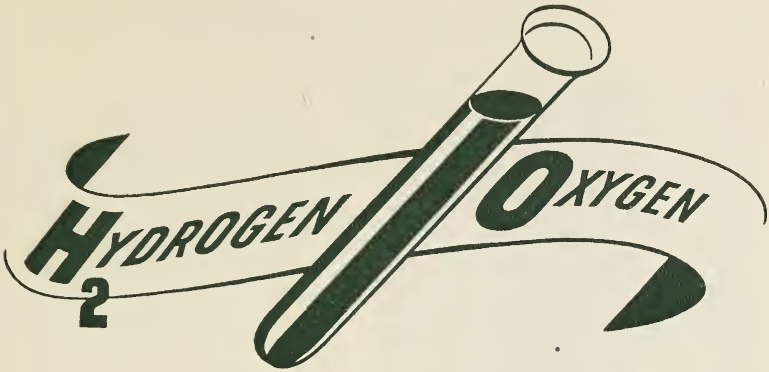
Centigrade (sĕn′tĭ·grād). (From the Latin *centum,* hundred, and *gradus,* degree). Divided into 100 degrees. Used to describe one kind of thermometer scale.

Graduating (from the Latin *gradus,* grade or degree). Marking off into degrees.

Density. The weight of one unit volume of a substance – one cubic foot, for example.

Calorie (kăl′ō·rĭ). The unit used to measure heat in the metric system.

Absorb. To suck up or take in.



CHAPTER 7 ________________ UNIT 3

What Is Water?

112. Is water a simple substance? You will recall that the Greek philosopher Aristotle was not an experimenter. He believed that all substances in the universe are made up of just four simple *elements:* air, water, earth, and fire. Galileo showed that Aristotle was wrong in his guess about falling objects. He was wrong in all four of his guesses about elements. *Air* and *earth* are *compounds,* or mixtures of several elements and compounds. Water is a compound. *Fire* is not matter, but the action seen when fuel burns. As the result of much patient work and many experiments by scientists from various nations, ninety-two elements have been discovered from which all known substances seem to be made. Just as we can make hundreds of thousands of words from only twenty-six letters in our alphabet, so it is possible for chemists to make hundreds of thousands of compounds from the ninety-two elements.

Henry Cavendish, a wealthy Englishman, was very unlike Aristotle. [See Fig. 7–1.] He seems to have spent nearly

FIG. 7–1. Henry Cavendish (1731–1810) was an English chemist. He discovered hydrogen, and learned the nature of water. Much research work is carried on today in an effort to conserve wealth or to create wealth. Cavendish was rich enough so that he did not have to work. He experimented because he liked to do so. When he grew tired of his experiments with hydrogen, he began the new problem of finding the density of our earth.

all his time trying one experiment after another. He never tried to make any money out of his experiments, but he performed his experiments just for the love of science as a hobby. He lived alone. In fact, he was so timid and reserved that he had a special stairway for his own use so he would not meet his servant on the main stairway. One of his important discoveries was the fact that water is not an element, or simple substance, but a compound made up of two elements, which are usually gaseous. One of the gases is hydrogen, which was named for the Greek words that mean *water producer*. The other gas is oxygen, which a French chemist later named from the Greek words which mean *acid producer*. Both of the gases, when pure, are without color, odor, or taste.

113. Can we prepare hydrogen by decomposing water? In order to try this experiment, let us connect two or three dry cells with the apparatus shown in Figure 7–2. The wires from the dry cells are connected with two pieces of plati-

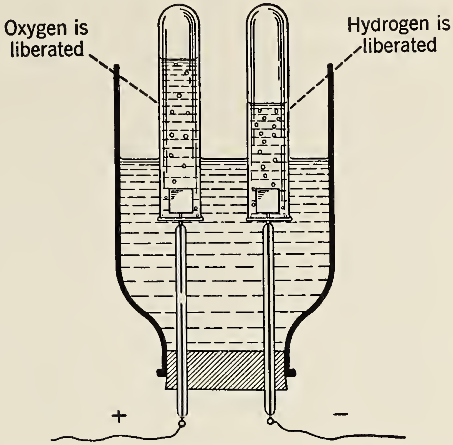


FIG. 7–2. Water may be decomposed by the use of the electric current. Oxygen is released as bubbles on the positive plate, and hydrogen is released as bubbles on the negative plate.

num, which are sealed in the glass tubes. The apparatus is then filled with water to which a small amount of sulfuric acid has been added. Water is not a good *conductor* of electricity, but it becomes a fairly good conductor when some acid is added to it. When the *circuit* (sûr′kĭt), or complete path of the electric current, is closed, the electricity flows through the water and splits it into the two gases, hydrogen and oxygen. The hydrogen bubbles are set free around that piece of platinum which is connected with the zinc, or to the negative plate of the dry cells. Oxygen bubbles are set free at the piece of platinum which is joined to the positive plate of the dry cells, or to the carbon rod. The volume of hydrogen set free is just twice the volume of the oxygen.

A chemist uses signs, or *symbols*, to represent elements. The symbol for hydrogen is represented by the capital letter H; the symbol for oxygen is the capital letter O. He also uses formulas to represent compounds. The formula for water is H_2O, which is read H-two-O. A formula is a kind of chemist's shorthand. The formula for water shows that each molecule of water is made up of *two atoms* of hydrogen and

one atom of oxygen. Thus you see that the atom must be even smaller than the molecule.

114. Can we repeat Cavendish's experiment? Is it possible to form water from a mixture of hydrogen and oxygen gases? Suppose one mixes two volumes of hydrogen with one of oxygen. Nothing happens. However, if a lighted match is now applied to the mixture, an explosion occurs. The hydrogen and oxygen unite chemically with each other. The product that is formed is water. (This is a teacher's demonstration and pupils should not do the experiment.) Thus the chemist takes water apart by using electricity. He finds it is made up of two gases, hydrogen and oxygen. He puts the two gases together again, and as they unite during the explosion, water is formed by the union of the two gases.

115. What kinds of changes occur in nature? You know that it is possible to break glass, or to cut a piece of wood up into shavings. We can easily identify the pieces as glass and wood, even after the change. We can freeze some water, and then apply heat to melt the ice that was formed. We may evaporate water and then condense the water vapor. In all these changes, the molecule has not been broken up, and the substance does not lose its identity. We call such changes in matter *physical changes.* Other examples of physical changes include the magnetizing of a piece of iron, the tearing of a piece of paper, the boiling away of alcohol, the freezing of mercury.

When we experimented by passing electricity through water containing a little acid, we split the molecules up into what the chemist calls atoms. The products resulting from this change did not resemble very much the water from which they were formed. The water lost its identity. One substance was separated into two different elements. We call such a change a *chemical change.* Other chemical

changes are the souring of milk, the rusting of iron, the tarnishing of brass, and the burning of wood.

116. How are changes in matter brought about? In order to produce changes in matter, we use some form of energy. We use *electrical energy* to break water up into its elements. We use *heat energy* to burn wood or to ignite a mixture of hydrogen and oxygen. We may use the *energy from some machine* to crush stone or to grind cement to a powder. Plants use *light energy* from the sun to make starch in their leaves. The photographer uses *light energy* when he takes your picture. The light energy acts upon some of the chemicals with which the plate or film is covered and brings about a chemical change. We need to remember that energy is the capacity for doing work and that man has at his command several different forms of energy.

117. How is water used as a standard of weight? If we are planning to measure something, we do it by comparing it with some standard. For example, you may use a foot rule or a yardstick to measure the length or the width of a room. The *yard* or the *foot* is the standard of length in the English system of measurement. In a newspaper account of the Olympic games, we see references to the 100-meter dash, the 200-meter dash, or the 1000-meter run. The word *meter* means measure. It is the standard of length in the *metric system* of weights and measures. [See Fig. 7–3.]

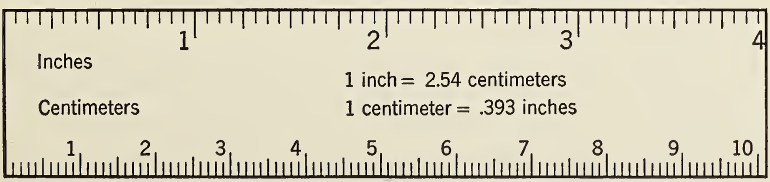


FIG. 7–3. The centimeter is nearly 0.4 of an inch in length. One inch equals 2.54 centimeters.

About twenty years after the thirteen colonies declared their independence from Great Britain and formed a new nation, the people of France found the extravagances of their king unbearable. The taxes they had to pay became so heavy that the people revolted and decided to do away with kings forever. They decided, too, to make some other changes, one of which is of great interest to us. They planned the metric system of weights and measures, which is the most sensible system ever devised. This system is now in general use in all civilized countries except Great Britain and the United States. It finds extensive use, however, in these two countries for all kinds of work in scientific fields.

Just as our dollar is divided into tenths, or ten-cent pieces, so the meter, which is a little longer than a yardstick, is divided into tenths. One tenth of a meter is called a *deci*-meter. Our dollar is divided, too, into hundredths, or into cents. In a similar manner, the meter is divided into hundredths. One-hundredth of a meter is called a *centi*-meter. It takes 2.54 centimeters to equal one inch. One one-thousandth of a meter is called a *milli*-meter. One thousand meters make one *kilo*-meter. A distance of one mile is equal to about 1.6 kilometers.

If we make a box exactly one centimeter long, one centimeter wide, and one centimeter deep, it will hold exactly one *cubic* centimeter. The amount of water needed to fill such

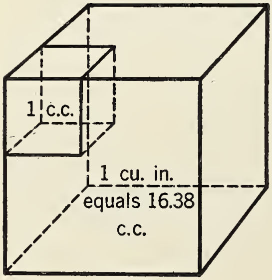
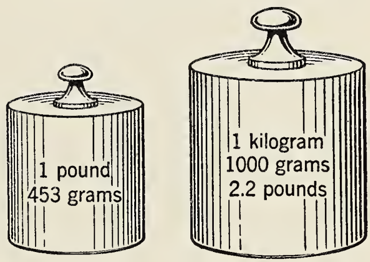


FIG. 7–4. The cubic inch contains more than 16 cubic centimeters. Since there are 1728 cubic inches in one cubic foot, it is easy to see that the cubic centimeter is a very small unit used to measure volumes. The cubic meter, which equals one million cubic centimeters, is in common use.

a box weighs just one *gram,* which is the *standard of weight* in the metric system. One thousand cubic centimeters of water weigh one *kilogram,* or 1000 grams. [See Fig. 7–4.]

Now you can see how the French Revolutionists used the weight of one cubic centimeter of water as the standard for their unit of weight. If we keep the temperature constant at 4° *Centigrade,* then the weight of pure water does not vary. The pound in the English system is supposed to equal in weight that of 7000 grains of wheat. If you have ever seen grains of wheat, you know they vary considerably in size and weight. [See Fig. 7–5.]

FIG. 7–5. The kilogram is more than twice as heavy as the avoirdupois pound. How would you proceed to find your weight in kilograms?



The gram is a very small weight. A new nickel, for example, weighs almost exactly five grams. In fact, if you were to lose a five-gram weight, you could use a nickel in its place without much error. The gram is much used in scientific work. Many doctors now write prescriptions in grams, and druggists use the gram in many of their weighings.

*118. **How is a thermometer made?** At some time you may have been careless enough to break a thermometer. You then found that the tube was made of thick glass with a tiny hole extending through its whole length. There was a bulb at one end of the tube. You probably noticed, too, that the bulb and part of the tube were filled with *mercury,*

* Starred problems are intended for rapid pupils only.

or what is commonly called *quicksilver.* Some thermometer tubes are filled with colored alcohol.

Sometimes we take something apart to learn how it was made before we attempt to make another one. A chemist may take a compound apart, just as Cavendish did with water, in an effort to find out of what it is made. In some cases, too, a chemist can put the atoms together again to make the compound, just as one can put together oxygen and hydrogen to form water. Possibly at some time you took an alarm clock apart to learn how it was made. Do you think you could put together again the parts of an alarm clock or a watch and have them tick again?

If we wish to make a thermometer, we start with a glass tube that has a tiny hole through its entire length. The glass at one end of the tube is softened by heating it, and a bulb is then blown at that end. Next we fill the bulb and part of the tube with mercury, and heat the bulb until the mercury expands and fills the entire tube. That drives all the air out of the tube. At this stage the open end of the tube is heated

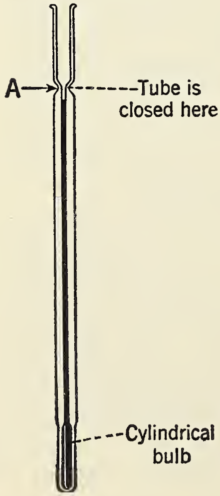


Fig. 7–6. A small-bore tube is used for making a mercurial thermometer. Of course, the bore of the tube must be of the same diameter throughout its length, if the degree marks are to be the same distance apart. The bore must have a small diameter, too. Then the thermometer will be more sensitive, because a slight expansion of the mercury in the bulb will push the mercury up higher in a smaller tube than it would in a larger one.

in a gas flame until the glass softens enough to seal it. [See Fig. 7–6.]

Before we can make a measurement of any kind we must have some place at which to begin, and some place at which to end or stop. Before we can mark off any degrees on a thermometer, we must have two *fixed points,* one at which to begin the markings and the other at which to stop. Here, too, we use water to find the two fixed points. For one of them we use the *freezing point of water,* and for the other we use its *boiling point.* Let us see how it can be done.

*119. **How do we find the freezing point?** Suppose you were given a thermometer tube and bulb, all properly filled and sealed but without a scale showing the degrees. The freezing point on a thermometer must show the temperature at which water will freeze. It is easier, however, to find the temperature at which ice melts, and it happens that *the temperature of melting ice is the same as that of freezing*

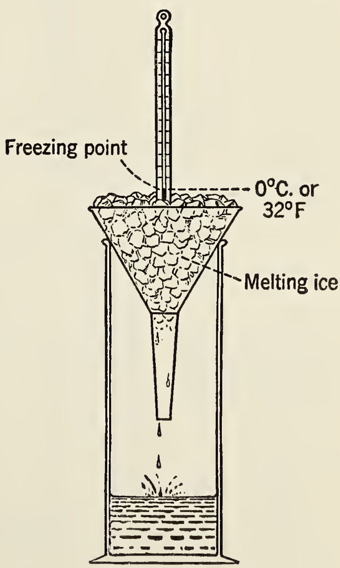


Fig. 7–7. Checking a thermometer for freezing point. This experiment or proof is made in a room warm enough so that the ice which is packed all around the bulb of the thermometer will be melting freely. If one tried to mark the freezing point on a thermometer by putting it in freezing water, he would find it more troublesome, and he would be likely to break the thermometer bulb.

water. Hence you would pack the bulb and lower part of the thermometer tube or stem in a large funnel containing melting snow or melting ice. [See Fig. 7–7.] You must allow about five minutes for the mercury and glass to cool down until they have the same temperature as the melting snow or ice. Then you will mark the point at which the mercury stands " Freezing point." That point may be etched on the glass stem of the thermometer by the use of a special acid, or it may be marked upon a frame to which the thermometer tube and bulb are securely fastened.

*120. **How do we find the boiling point?** Having used melting ice to find the freezing point of our thermometer, we then proceed to find the boiling point. We can do this by suspending the bulb and most of the stem in steam that

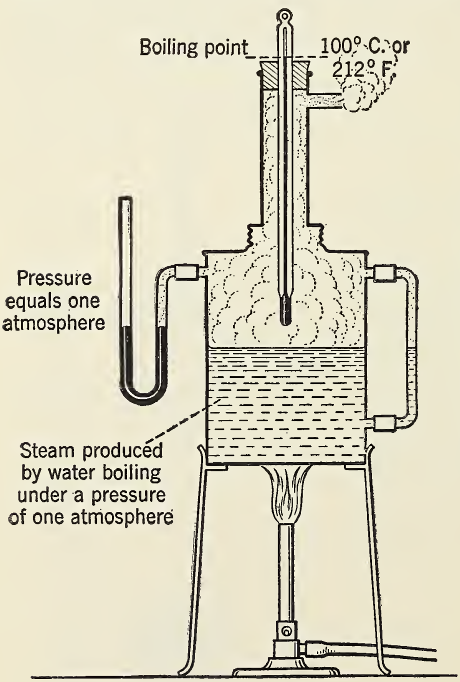


Fig. 7–8. To find the boiling point of a thermometer, we surround the thermometer with steam and mark the highest point to which the mercury rises the *boiling point.* Some mercury may be placed in the U-shaped tube to make sure that the water is boiling under the same pressure it would have at sea level.

arises from boiling water. [See Fig. 7–8.] The highest point to which the mercury rises is marked the boiling point. If we wish to be accurate, we must use water that is boiling at *sea-level pressure.* At a higher altitude, boiling water is not so hot, as we have already learned. The spaces between the freezing point and the boiling point are marked off into degrees. This is called *graduating* the thermometer. Two common scales are used for graduating thermometers, the *Fahrenheit* and the *Centigrade.*

*121. **How is the Fahrenheit thermometer marked?** On the Fahrenheit thermometer the *freezing point* is marked 32° F., and the *boiling point* is marked 212° F. The difference in temperature between the two fixed points is 180 Fahrenheit degrees. In most cases the space between the two fixed points on the stem of the thermometer is divided into 90 equal parts, or into two-degree divisions. Here again the numbers may be etched on the glass stem, or on the frame to which the thermometer is securely fastened. [See Fig. 7–9.]

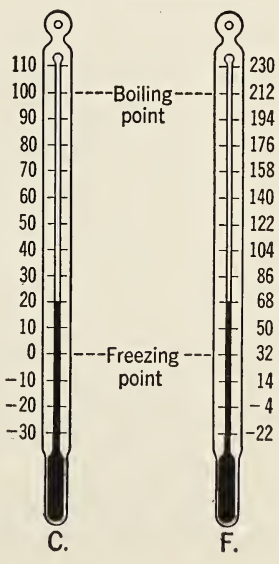


FIG. 7–9. These diagrams show how the Fahrenheit thermometer, with which you are familiar, compares with the Centigrade thermometer. It is possible to have a long vertical line etched on a thermometer tube, and then have such a tube graduated in the Centigrade scale on one side of the line and in the Fahrenheit scale on the other side. Why do you suppose the Centigrade thermometer is used by scientists? Would you like to change to the Centigrade thermometer? There are some persons who believe it would be wise for us all to use the same scale for all purposes. Can you think of any reasons for continuing to use the Fahrenheit thermometer?

*122. **How is the Centigrade thermometer marked?** If you wish to graduate a thermometer on the Centigrade scale, you mark the freezing point 0° C., and the boiling point 100° C. The space between the two fixed points is then divided into 100 equal spaces, or degrees. The Centigrade thermometer is used in nearly all countries except the United States and the British Empire for practically all purposes. Although it is used to some extent for scientific work in these two countries, yet the Fahrenheit thermometer is used for weather observations.

*123. **How do Centigrade readings compare with Fahrenheit readings?** You have a friend who bought a Centigrade thermometer in Paris. You visit him and notice that the thermometer in his living room reads 20° C. You may have felt comfortable until you looked at his thermometer. Now you probably begin to feel chilly. You begin to wonder what your Fahrenheit thermometer would read if it were placed beside his thermometer in the same room. Can you figure it? Let us use an example. There are 100 Centigrade degrees between the boiling point and the freezing point. There are 180 Fahrenheit degrees between the boiling point and the freezing point. Therefore, 100 Centigrade degrees must equal 180 Fahrenheit degrees, and *1 Centigrade degree equals 1.8 Fahrenheit degrees.* Then, 20 Centigrade degrees must equal 20×1.8, or 36 Fahrenheit degrees. The temperature of the room is 36 Fahrenheit degrees above the freezing point, which on your thermometer is 32° F. Your thermometer would read 68° F. $(36 + 32)$.

To change Centigrade readings to Fahrenheit readings, you merely *multiply the Centigrade reading by 1.8, and add 32 degrees.*

If a Frenchman were visiting in America, he would not be familiar with our thermometers at all. Suppose he sees one

that reads 86° F. How can he change that reading to a Centigrade reading? Of course he must just reverse the process given in the preceding paragraph. To change Fahrenheit readings to Centigrade, *subtract 32 degrees from the Fahrenheit reading, and then divide the remainder by 1.8.* For example, 86 — 32 = 54. And, 54 ÷ 1.8 = 30. Hence, 86° F. = 30° C. From the explanation just given, we can see how water, our most useful and most abundant liquid, is used as a standard in graduating thermometers.

124. What is density? It is careless to say that lead is *heavy* and that aluminum is *light.* A large block of lead is indeed *heavy,* but a tiny pellet of lead the size of a birdshot is *not heavy.* A large piece of aluminum may be much heavier than a small piece of lead. What expression should one use? To be correct, one should say: "Lead is a *dense* metal."

When a scientist uses the word *density,* he refers to the weight of *some particular volume* of a substance, one cubic foot, for example. *One cubic foot of water weighs 62.4 pounds.* That is the density of water. A block of lead one foot long, one foot wide, and one foot high (one cubic foot) weighs 705 pounds. Lead is more than eleven times as *dense* as water, which is used as a *standard.* Gold is more than nineteen times as dense as water. Hence a cubic foot of gold weighs more than 1,200 pounds. A cubic foot of cork weighs only about 15 pounds, and balsa wood is only about half as dense. Substances which are less dense than water will float

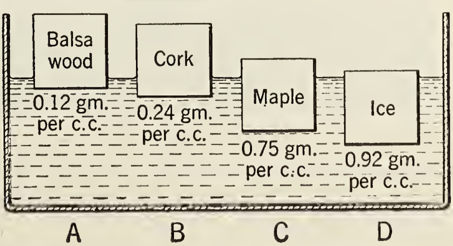


FIG. 7–10. Some floating objects sink more deeply than others. Can you see from this diagram reasons why cork and balsa are useful for many purposes?

upon water. [See Fig. 7–10.] Objects which are *more dense* than water will sink in water, unless they are broadened out like a boat so that they displace their own weight of water. Do you think that you are denser than water? Will it matter whether your lungs are full of air, or whether you have breathed out as much air as you can?

The amount of sea water needed to fill a box one foot long, one foot wide, and one foot deep weighs 64 pounds. Hence sea water is slightly denser than fresh water, because the salt and other minerals dissolved in it increase its density. Possibly you can now explain why it is easier for a person to float in sea water than it is for him to float in fresh water.

All objects submerged in water lose *part* of their weight. If the object is less dense than water, it appears to lose all its weight. An iceberg is about nine-tenths as dense as water, and for that reason nine-tenths of the bulk of an iceberg is beneath the surface of the water in which it floats. [See Fig. 7–11.]

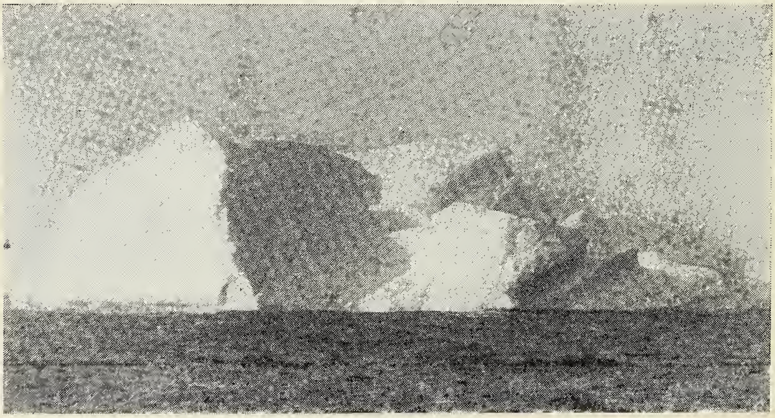


FIG. 7–11. Only about one-ninth or one-tenth of an iceberg is above the water as it floats. If an iceberg is 200 feet above the water, it may extend from 1600 to 2000 feet below the surface. (*Courtesy Roy Fitzsimmons*)

125. How is heat measured? We use a thermometer to measure temperature, but we cannot measure heat in degrees. We measure heat in *calories.* Many persons talk glibly about " eating calories " or of " counting their calories." Hence one may get the mistaken idea that a calorie is some new breakfast food, a slice of bacon, a baked potato, a dish of ice cream, or a piece of chocolate candy. In science, heat is measured in terms of what it can do, and we use water as a standard. *One calorie of heat can warm one gram of water one degree Centigrade.* When one *gram* of water cools through one degree Centigrade, it gives off one calorie of heat. To warm 100 grams of water one degree Centigrade, we must add to it 100 calories of heat.

We eat in order to nourish the body and to supply us with energy, thus keeping *the body warm.* We can see, therefore, why the amount of food we eat is related to the number of calories of heat that food can furnish us. Our food, as fuel, supplies enough heat to our bodies to keep them at a temperature of about 98.6° F. Some foods, such as starch, sugar, and fat, supply more calories per pound than other foods do. Biologists and those who work out diets use the *large Calorie,* which is 1000 times as big as the calorie which was defined in the first paragraph of this section.

126. How fast does water heat? Let us try an experiment to see whether water or iron warms up more quickly. We can put a seven-pound flatiron on one burner of a gas stove, and seven pounds of water in a pan over another similar burner. We can use a thermometer to check the temperature from time to time. If the experiment is performed carefully, we shall find that the iron rises in temperature *about nine times* as fast as the water. In other words, water *absorbs* more calories of heat in warming one degree than an equal weight of iron does. If we compare it with aluminum,

we find that a given weight of aluminum warms up about five times as fast as the same weight of water, and copper heats almost eleven times as fast as water. Scientists have found that it takes more calories to warm one pound of water one degree than it does to warm an equal weight of any common substance through one degree. We find that *water warms rather slowly* because it requires much heat to warm it. You have probably noticed that it takes rather a long time to heat a pan of water up to its boiling point.

127. How fast does water cool? Since water absorbs so much heat as it grows warmer, we would expect it to cool slowly, too. It can be shown that it does cool slowly. One pound of water holds nine times as much heat as one pound of iron. [See Fig. 7–12.] For that reason iron cools much

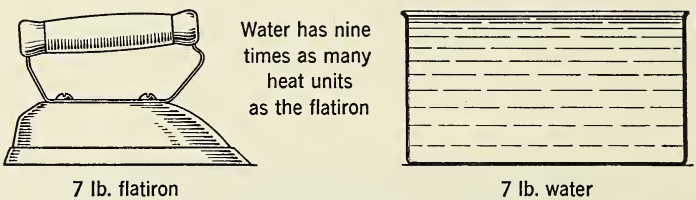


FIG. 7–12. Water warms slowly and cools slowly.

more rapidly than does water. *Water cools more slowly* than an equal weight of any common substance. Water loses more heat in cooling a given number of degrees than other common substances do. Hence hot water when cooling gives out heat to its surroundings.

128. How are you affected by the slow cooling and warming of water? Can you explain why a hot-water bottle is so efficient when used to keep a sick patient warm? If you swim in a lake in the spring, you find that the water is cold, even though the air and the land may seem warm. In the spring the air and land are warmed faster than water. If you

swim in the same lake in the fall, you may find that the water is warmer than the air or the land. The lake water cools off slowly. If we keep in mind the slow warming and the slow cooling of water, we can understand why large bodies of water moderate the climate of places located near them. San Francisco, on the Pacific Ocean, is warmer in winter and cooler in summer than St. Louis, which is in the heart of the United States. Portland and Seattle have more temperate climates than have Minneapolis and St. Paul. Water may carry heat from one place to another. Warm ocean currents have a marked effect upon the climate of Alaska and Norway, for example. A cold current from the Arctic Ocean helps to make the climate of Newfoundland and Labrador colder than it would otherwise be.

Questions

1. Why do you think that water is used as a standard for the metric units, for density, for heat units, and for graduating thermometers?
2. From the fact that clouds float in the air, do you think that water vapor is denser, or less dense, than dry air?
3. What kinds of changes take place in nature? What are some ways in which changes in matter are brought about?
4. If you have ever spent much time in a place where there are high mountains, you probably have noticed that the top of a high peak is likely to be hidden by a veil of clouds. Explain why.
5. Why is it unscientific to say that iron is a " heavy " metal?
6. Does water expand or contract as it freezes? How does the density of ice compare with that of water?
7. Which method of solving problems is more effective, that of Aristotle or that of Cavendish?
8. Platinum is 21.4 times as dense as water. What does one cubic foot of platinum weigh? If someone made you a gift of

one cubic foot of platinum, all in one block, could you carry it home? (The market price of platinum usually varies from \$30 to more than \$100 per ounce.)

9. Can you change 40° C. to the corresponding Fahrenheit temperature?

10. A Fahrenheit thermometer reads 110° F. What would a Centigrade thermometer read, if placed alongside the Fahrenheit thermometer?

Some things for you to do

1. If you have a thermometer at home, check the correctness of its freezing point by packing the bulb in *melting* snow or cracked ice.

2. Ask your instructor to mix four parts, by weight, of fine iron filings, with seven parts, by weight, of powdered sulfur. Fill a test tube one-fourth full of such a mixture. Heat it strongly. It soon starts to glow. When it has stopped glowing, let it cool. Then break the tube. Examine the product that is left. Does it resemble sulfur? Is it attracted by a magnet in the same way that the iron filings are? What kind of change occurs in this experiment?

3. Float a block of balsa wood on water, and also blocks of cork and various kinds of wood. Float a piece of paraffin, too. Make a list of all these materials in the order of their relative densities.

4. Pour a few cubic centimeters of a solution of silver nitrate into a test tube and then add a few cubic centimeters of a solution of common table salt in water. The white solid that is formed is sensitive to light. Hold the test tube in direct sunlight for a few minutes. What do you see?

Living Things Need Air

We found that water is the most abundant liquid in the world. Air is the most abundant gas, or mixture of gases. It makes up the atmosphere which surrounds the earth. It is like a great ocean. We live at the bottom of that ocean of air, and walk around on the bottom of that ocean. If we have a balloon, we may float around in the air at some distance above the earth.

Much of the time we are not even conscious that air exists. But we could live only a few minutes without it. When the wind blows, rustling the leaves, swaying the branches of the trees, carrying away our hats, or even uprooting large trees, then we are conscious of the air in motion. If we hold a hand out of a window of a moving car, we can feel the pressure of the air which the car pushes aside.

As you study this unit, you will find proof that air is real and that it can be weighed. You will understand how it presses down upon our bodies. You will find out that this

pressure is different at the bottom of a mine and at the top of a mountain – and even different in the same place at different times. You will read about the instruments which men use to measure the pressure of air, and how these instruments help them to forecast the weather.

You will find, too, that air is a mixture of gases, and that the water vapor which the air carries supplies us with rain.

Think about these!

1. We cannot see, smell, or taste air. How can we be certain that it exists?
2. You have seen feathers floating in the air. Do you think they were more dense or less dense than the air itself?
3. Does the air extend upward indefinitely? What are some of the best-known attempts of man to explore the higher regions of the atmosphere?
4. Does the pressure of the air ever vary? If so, how do you think it would vary in different altitudes?

Words for this chapter

Tornado. A whirling windstorm of great violence.
Velocity (vė·lŏs′ĭ·tĭ). The rate of motion, or the speed.
Inflate. To enlarge by crowding in more air or gas.
Exhaust. As used here, to remove the air from a container.
Valve. A device which permits flow in one direction.
Pressure. A force which may cause a push or a pull.
Altitude. Height, or elevation.
Stratosphere (strā′tȯ·sfēr). The portion of the atmosphere above the highest clouds.
Gauge (gāj). An instrument used for measuring.
Barometer (bȧ·rŏm′ė·tẽr). An instrument used to measure air pressure.
Automatically. Acting of its own accord.
Aurora borealis (ô·rō′rȧ bō′rė·ā′lĭs). Northern lights; lights sometimes seen in the sky, most clearly in the Arctic regions.

CHAPTER 8 ———————— UNIT 4

How Does Air Act?

129. What is the atmosphere? We can see the ocean in which fish and many other creatures live. We ourselves live at the bottom of a huge ocean of air called the *atmosphere;* but we cannot see the ocean of air, because it is made up of several colorless gases. We cannot smell the air, either, or taste it. There are other ways, though, in which we can tell that this ocean of air exists. When there is a wind, we can see the air picking up dust, leaves, and bits of paper. We may hear the air, too, as the wind howls around the corners of our houses and whistles at our windows. We can feel the air when we are moving through it quickly.

If we try to ride a bicycle against the wind, we find it difficult, because the air is a real substance through which we must push our way. During a *tornado,* when the *velocity* of the wind may be 200 miles or more per hour, the force of the wind may overturn buildings or uproot and break off tall trees. [See Fig. 8–1a and b.]

Fig. 8–1a. Few things on earth can withstand the fury of a tornado. Trees are torn down and buildings are overturned by these twisters. (*Courtesy U. S. Weather Bureau*)

Fig. 8–1b. *Tornado* is a Spanish word meaning *twister*. The speed of the whirling movement of a tornado is thought to be as much as 400 or 500 miles an hour, in some cases. Such a twister will destroy anything in its path. Tornadoes are too common in some Middle Western states, where the approach of a funnel-shaped cloud is a warning to those living in such areas to take refuge in a so-called " cyclone cellar." Tornadoes are commonly, though incorrectly, called " cyclones."

When we speak of the atmosphere, we mean that vast sea of gases that surrounds the entire earth. It is present over the ocean and over the land. It fills our valleys, and it extends far above the tops of our highest mountains.

130. Does air have weight? Possibly you have heard someone say that some object was "as light as air," just as if air had no weight at all. If we really wish to learn whether air has weight, we must plan some experiment by means of which we can weigh it. You know that you can *inflate* a bicycle tire or a basketball by pumping air into it. You use one kind of air pump to *compress* the air, or to crowd more air into the container. There is a different kind of air pump which can be used to pump air out of a container and to produce a partial vacuum in it. Such a pump, used to *exhaust* the air from a container, is called an *exhaust* pump.

Because it is possible to pump air from one vessel into another in much the same way that we pump water, we can perform a simple experiment to find out the weight of air. First we weigh a small hollow brass or glass sphere (sfēr), which is fitted with a tube and a *stopcock,* or *valve.* [See

FIG. 8–2. A baroscope globe weighs less when the air is pumped out of it than it does when full of air. If we use a bicycle pump to force more air into such a globe, it will weigh still more than it did before. Have you ever pumped up an automobile or a bicycle tire? If you have, you may have lifted it before, and again after, putting air into the inner tube. Could you notice a difference in weight when the tire was inflated?

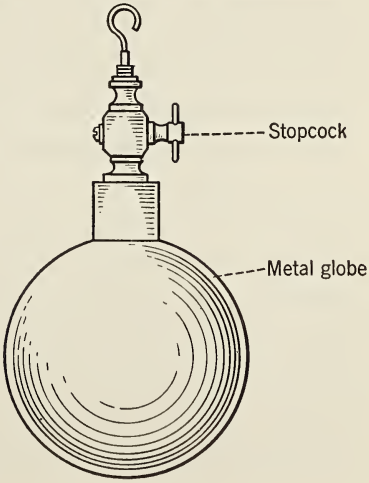


Fig. 8–2.] Next we attach the sphere to an air pump and proceed to pump from the sphere all the air that we can pump out. Then we close the stopcock so that the air cannot flow back into the sphere after we have removed the pump. A second weighing of the sphere will show that it has lost weight. *The loss of weight must have been caused by pumping the air out of the sphere.* When we open the stopcock, we can hear a hissing sound as the air rushes back into the sphere. Does the sphere now weigh as much as it did at first?

131. How much does air weigh? In the last section we proved that air has weight. We are interested, too, in learning how much a given volume of air weighs. Scientists have performed many experiments similar to the one we performed in section 130, and have taken the average weight of air from these experiments. The scientists have found that *one cubic foot of air at sea level weighs a little more than one and one quarter ounces.* One cubic foot of water weighs 62.4 pounds. Therefore, the scientists have calculated that water is about 773 times as dense as air at sea level.

If we compare the weight of air with the weight of many other things, we find that it is light, but it is about fourteen times as dense as hydrogen, the gas which is a part of water. If your bedroom is 13 feet long, 12 feet wide, and a little more than 8 feet high, it holds a little more than 100 pounds of air.

132. Do you feel the pressure of air? As we walk around on the earth's surface, we do not feel any *pressure* or push from the air, because the air outside our bodies pushes equally upon us from all directions at the same time. The pressure from inside our bodies is about equal to the pressure outside. We grow accustomed to such equal and constant pressure. If we go down into a deep mine, where the air pressure on our bodies is greater than that to which we are accustomed, then we become conscious of the increased

Fig. 8–3. In this thick-walled bathysphere, Dr. William Beebe has gone down into the ocean to study the animals that live in the deep seas. He has gone down as far as 3028 feet. He has made some interesting pictures of the strange creatures which live in the depths of the ocean. No doubt you will enjoy reading his account of some of his explorations. (*Press Association*)

pressure. We notice particularly the increased pressure upon our eardrums. If we dive down into water to a considerable depth, we feel an increase in pressure. [Fig. 8–3.] The deeper we go into the water, the greater the pressure, or push, becomes. We have added the pressure of the water to the air pressure at the surface of the water.

If we go to the top of a tall building, or to the top of a high mountain — Pikes Peak, for example — we notice that the air pressure becomes less. Some persons grow faint or dizzy at such heights. In some cases, blood may start to flow from the nose because the outside air pressure is reduced. The inside pressure is relatively greater, and the blood vessels are unable to withstand the pressure of the blood. Such " thin " air contains less oxygen, so airplane pilots who fly at high *altitudes* carry oxygen tanks with them. The tanks supply them with a sufficient amount of oxygen when they rise to heights at which the air may be only half as dense as it is at sea level. In *stratosphere* flights, men ride in a strong cabin,

or *gondola,* in which the composition and pressure of the air inside is regulated by oxygen tanks and other equipment.

133. **How great is the air pressure?** To answer this question, we shall perform another experiment. We use a small bell glass like that shown in Figure 8–4. A thin sheet of rub-

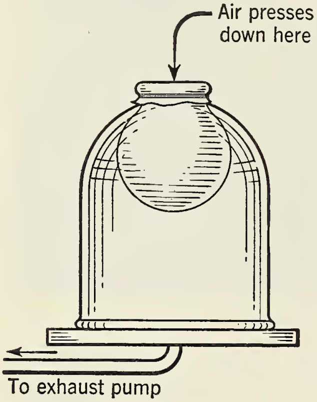


FIG. 8–4. Before we start the air pump, the rubber sheet is flat, or level. When we remove the air from the bell glass by the use of the air pump, the rubber is pushed downward into the bell glass by the weight of the air above it.

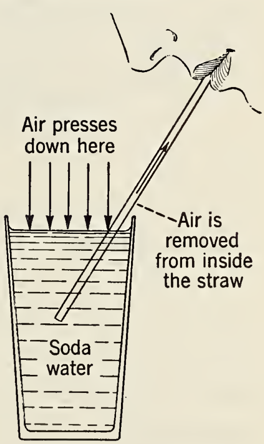
ber is stretched over the top opening and fastened securely. The bell glass is then placed on the plate of an exhaust pump. When the pump is operated, the air below the rubber sheet is gradually removed. The air above the rubber then presses it down into the bell glass. If we continue to exhaust the air, the rubber may burst. You can get a good idea of the force which the air exerts, by holding one hand tightly over the opening in the bell glass while another pupil operates the pump.

By accurate experiments, it has been found that the air presses upon every square inch of any surface at sea level with a force of 14.7 pounds. Make a square, one foot on a side, on the floor of your schoolroom. The entire force of the air pushing downward on that square foot of area is more than 2,100 pounds.

If we go to the top of Mont Blanc in Europe, we find that the air pressure is only about one half so great as it is at sea level. Is that what we should expect? It seems reasonable to believe that air pressure grows less and less as we go higher and higher into the ocean of air in which we live. It is true, too, that those who live in the valleys are in a deeper ocean of air than those upon the mountain side. As we go deeper and deeper into water, the pressure grows greater and greater, and the same thing applies to air.

134. How do we use air pressure? The clerk at the soda fountain hands you a straw for your soda. If you could see the air above the soda water in your glass, you would get a picture of the air molecules pressing down upon the surface at every point, within the straw and around it. [See Fig. 8–5.] When you suck upon the straw, you remove some of

Fig. 8–5. As air is sucked out of the straw, the space inside becomes a partial vacuum. Air which presses down on the surface of the soda water pushes the liquid up the tube. Could you suck soda water through a straw if the glass were in a vacuum?



the air and some of the pressure, therefore, from the surface of the liquid *inside the straw.* The pressure on the liquid is therefore unbalanced. The *greater* pressure on the surface surrounding the straw pushes the liquid up through the

straw. We sometimes say that a liquid "rises" in an exhausted tube, but it is more exact to say that the liquid is "pushed up" the tube by the pressure of the air surrounding the tube. We shall learn later, too, that air pressure is useful in medicine droppers, and in the operation of water pumps.

By the use of a *compression* pump, we can crowd more and more air into a bicycle tire or an automobile tire. [See Fig. 8–6.] In fact, we can burst a tire by doing so. In pumping

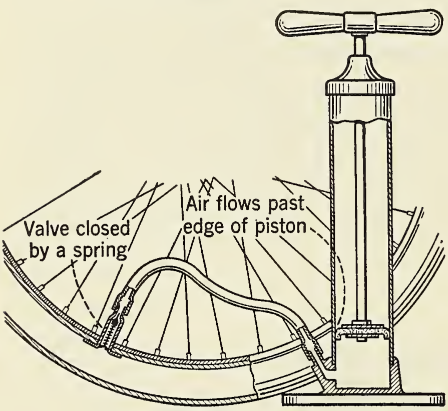


FIG. 8–6. A simple compression pump used to inflate a pneumatic tire.

up a tire, we crowd more and more air molecules into the space inside the tire. The molecules cause increased pressure as they move about inside the tire, and seem to struggle to get out. If we apply a *gauge* to the valve stem of the tire, we may find that it reads 30 pounds per square inch. That means that the pressure outward on the inside walls of the tire is 30 pounds more per square inch than the air pressure inward on the outside walls of the tire. We like to ride on an air cushion, because the compressed air is very springy.

Compressed air can be used to operate drills for drilling holes in rock or for tearing up pavement. It is supplied to men who work under water in diving suits. It may be used

to operate the brakes on streetcars, motor trucks, or trains.

When we clean a rug by means of a vacuum cleaner, we use a fan driven by an electric motor to push the air away from one side of the nozzle. Thus a partial vacuum is formed. As the air is pushed into this partial vacuum, it carries with it the lint, dust, and dirt from the rug or carpet. [See Fig. 8–7.]

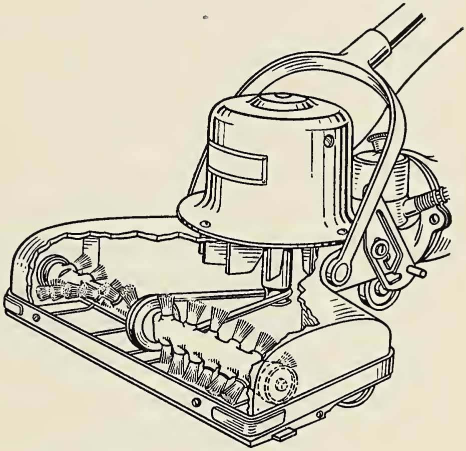


FIG. 8–7. The revolving brush beats the rug gently, and the dirt is pushed into the partial vacuum produced by an electric motor.

135. What was the Duke of Tuscany's problem? One might ask the question, "How high can water be pushed up an exhausted tube by the pressure of the air?" That question was answered about the middle of the seventeenth century. The Duke of Tuscany had a well dug and a pump placed in the well. He found that the water would not rise in the tube, or pipe, of his pump if the surface of the water in his well was more than about 30 feet below the level of the ground.

The Duke of Tuscany did not know why he could not get any water from his rather deep well, because at that time no one knew why liquids "rise" in exhausted tubes. The old

explanation was that "Nature has a horror of a vacuum." The ancients believed that when a vacuum is formed, nature tries to fill it up with something. It affords an amusing explanation, but we can see how silly it is if we try to picture a vacuum (nothing) pulling something (water, for example) up a tube. The Duke took his problem to the aged philosopher Galileo. Galileo passed the problem on to his brilliant pupil, Torricelli (tŏr′rē·chĕl′lē).

136. How did Torricelli solve the Duke's problem? No one knows whether Galileo knew the answer to the problem which he asked Torricelli to solve. A scientist needs imagination. Torricelli guessed that the air by its pressure *pushes* liquids up into exhausted tubes. He suspected that such pressure is not great enough to push water any higher than from 30 feet to 34 feet. He reasoned that mercury, a liquid which is *more than thirteen times as dense as water,* would rise less than *one thirteenth as high as water.* To test his views, he performed the following classical experiment.

Torricelli took a glass tube about three feet long, closed at one end, and filled it with mercury. Of course, the mer-

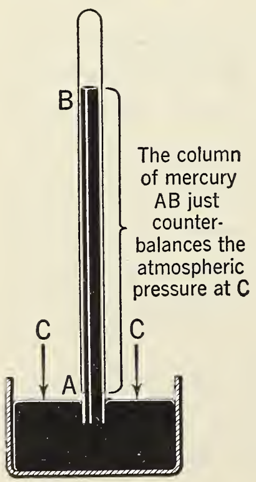


FIG. 8–8. A Torricellian apparatus, which can be used as a barometer by attaching to it a yardstick or other measure. One early barometer was made of water. The tube was more than thirty feet long; the bottom of it was in the basement of the owner's house, and the top extended out through the roof. Because the owner could foretell the weather, the neighbors accused him of witchcraft and made him destroy his barometer.

cury pushes all the air out of the tube, because it is impossible for two things to occupy the same space at the same time. He then placed his thumb over the open end of the tube to keep the mercury from flowing out of the tube as he turned it upside down and lowered the open end into a bowl of mercury. [See Fig. 8–8.] When he removed his thumb, only a small part of the mercury flowed out of the tube. Just as Torricelli suspected, the air pressure is great enough at sea level to hold up a column of mercury about thirty inches high. When such an apparatus is carried up a mountain, where the air pressure is less than it is at sea level, the column of mercury becomes shorter. At a height of 3½ miles, the mercury column is only about half as tall as at sea level. A column of mercury one inch square and 30 inches high weighs 14.7 pounds. Hence Torricelli's experiment furnishes us with a method of measuring the pressure of the atmosphere.

137. How is a barometer made? From Torricelli's experiment to the making of a *barometer* there is only one small step. We merely attach a measuring stick (a yardstick or a meterstick) to the tube of the apparatus of Figure 8–8. Then we can read the height of the mercury column above the height of the mercury in the bowl. [See Fig. 8–9.]

We have learned that the height of the mercury column in a barometer decreases as we carry it above sea level. It increases if we carry it down into a deep mine. Hence the barometer is used to measure altitudes as well as pressures. The mercury falls about one inch if we ascend 900 feet. A barometer which is marked to read heights directly is called an *altimeter* (ăl·tĭm′ē·tẽr).

Even at sea level the reading of the barometer varies from day to day and at different hours of the same day. It varies with the temperature and also with the amount of moisture which the air holds. Therefore it is used in making weather

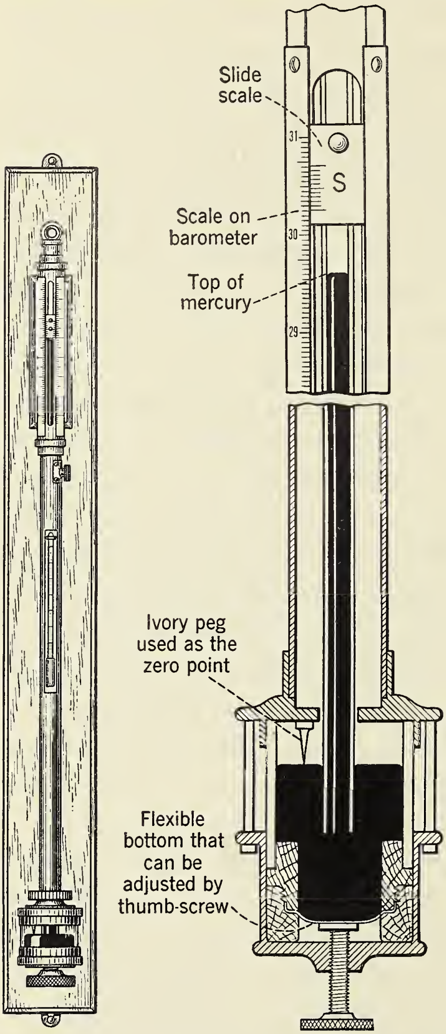


FIG. 8–9. The barometer is used to measure air pressure. The figure on the right shows the top and bottom of the figure on the left, enlarged. The mercurial barometer must be hung in a vertical position if it is to be read accurately. Before one reads the barometer, the thumb-screw at the bottom is turned enough to make the ivory peg touch the surface of the mercury. Then the slide scale is raised or lowered until its lower edge reaches the top of the mercury column. The reading may then be taken.

forecasts. Water vapor is less dense than dry air. The more moisture there is in the air, the lower the barometer reading. *Low barometer readings are associated with warm, cloudy, and rainy weather. High barometer readings are associated with clear, cool, dry weather.* In our later study of science

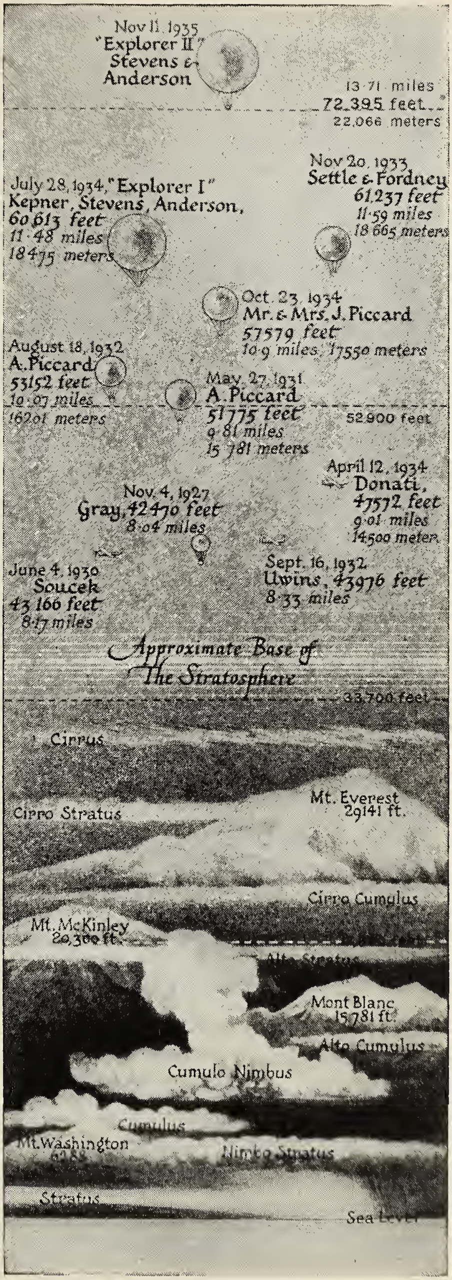


Fig. 8–10. Possibly you have heard the old Greek myth about Icarus, who had a pair of wings made of wax. According to the legend, he flew so high that his wings melted and he fell into the sea. About the time of the Revolutionary War, the two Montgolfier brothers, in France, invented a balloon made of pack cloth covered with paper. They experimented with hydrogen gas, which they found escaped too easily. They finally used gas obtained by burning wool and moistened straw, and succeeded in raising a balloon 35 feet in diameter to a height of 6000 feet. About seventy years ago, gliders were built and operated; and at the turn of this century, the Wright brothers invented the power-driven airplane.

Man is now constantly striving to reach higher altitudes by flights into the stratosphere. Nearly every year some aviator soars a little higher and establishes a new altitude record. In military service aviators are interested also in the rate of climb. (*Courtesy "The National Geographic Magazine"*)

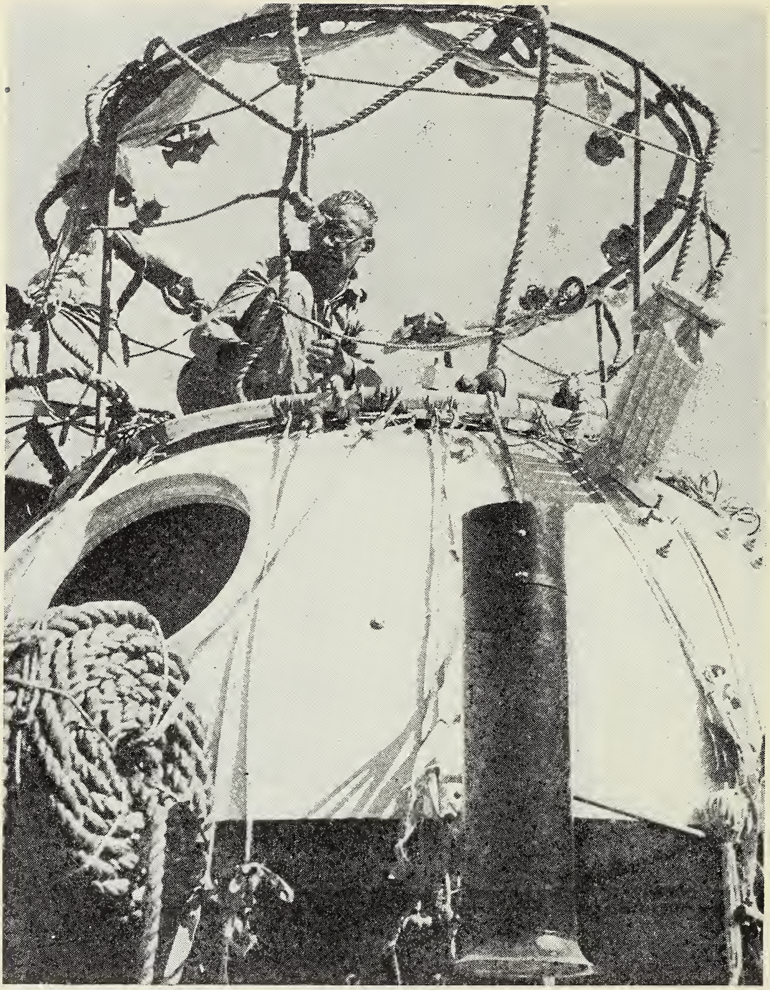


Fig. 8–11. Formerly persons who went up in a balloon rode in an open basket, hanging from the gas bag by ropes. In the record-breaking flight of the *Explorer II,* a large sphere, called a *gondola,* was used instead of a basket. This gondola, seen here before being attached to the balloon, was 9 feet in diameter. It carried a radio and a movie camera for taking films from the air, and it was air conditioned. The men in it took samples of air from various altitudes. (*Courtesy of Major H. Lee Wells, Jr., Omaha, Nebraska*)

we shall learn how a much more convenient type of barometer, without any liquid, is made.

138. How high is the atmosphere? It is a well-known fact that the air grows thinner and thinner, or less and less dense, as one goes higher and higher. No one knows how high one would need to go to reach an elevation where there is no air at all. Figure 8–10 shows the results of the various attempts which aviators have made to break altitude records.

Men are ambitious. Aviators have driven their planes upward into the stratosphere far above the level at which clouds are formed. On the twelfth of April, 1934, Commander Donati, of the Italian air force, ascended in his plane to a height of 47,572 feet, or a trifle more than 9 miles. Man reached his greatest height on the eleventh of November, 1935, when two Americans, Captains Stevens and Anderson, were sealed in a metal gondola attached to *Explorer II,* and were carried by this huge balloon to an elevation of 72,395 feet. [See Fig. 8–11.] They made their flight for the purpose of getting facts about the conditions at high altitudes. Many different kinds of instruments were carried by them to record *automatically* the temperature, the air pressure, the color of the sky, the presence of dust particles, and other things of scientific interest at a height of 13.7 miles. [See Fig. 8–12.]

Self-recording instruments have been carried by rather small balloons to a height of about 24 miles. There is enough air at that altitude to float such balloons. The instruments which are released when the balloon bursts are protected, by the use of small parachutes, from injury due to rapid fall and sudden crash. Scientists also estimate the height of our atmosphere by observing the elevation of meteors, which begin to glow as they are heated white hot by friction in entering and passing through our atmosphere. They also estimate the height of the atmosphere by observing the height of the

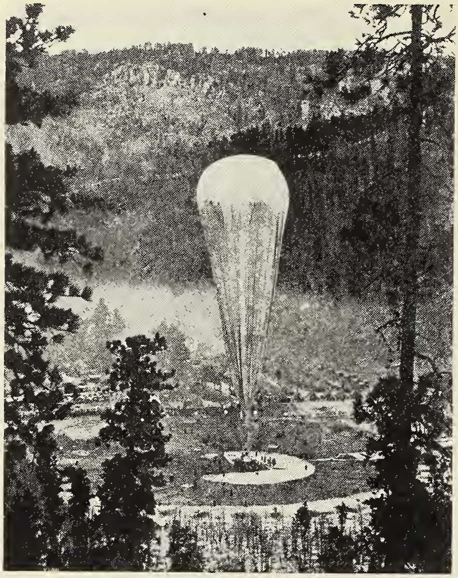


FIG. 8–12. The *Explorer II,* almost ready for its record-breaking flight up into the stratosphere. The gas bag was 192 feet in diameter, and it was filled with 3,700,000 cubic feet of helium. (*Courtesy of Major H. Lee Wells, Jr., Omaha, Nebraska*)

aurora borealis, or northern lights. From such observations they feel that the air must extend upward for at least 125 miles. It is possible, too, that there may be some extremely thin air at a height of from 400 to 500 miles.

QUESTIONS

1. If you cannot see air, how do you know that it really is made up of matter?
2. How would you prove that air has weight?
3. Does the atmosphere cover the ocean as well as it does the land?
4. Explain how it is possible to suck milk through a straw.
5. Can you pour water into a narrow-mouthed bottle if you do not furnish an opportunity for the air inside to get out? Explain.
6. How could you make a barometer?
7. For what purposes is a barometer used?

8. Would you expect the mercury in a barometer to rise or fall if you carried the barometer to the top of Pikes Peak?

9. Would you expect the mercury in a barometer to rise or fall if you carried it to the surface of the Dead Sea in Palestine, where the elevation is about 1300 feet *below* sea level?

10. Does the mercury in a barometer rise or fall as the amount of moisture in the air increases?

11. Explain why it is difficult to make ice cream slide out of a box, even if it has been loosened on all sides.

12. What is the air pressure in a flat tire? What would a tire gauge show?

Some things for you to do

1. Read the account of a flight into the stratosphere, in *The National Geographic Magazine* for January, 1936.

2. Into an empty varnish can, pour enough water to cover the bottom to the depth of almost an inch. Heat the water to boiling. Turn off the heat, and stopper the can tightly. What happens when cold water is run over the outside of the can? Why?

THINK ABOUT THESE!

1. Which one of the gases present in the air is of most value to us? Carbon dioxide is not poisonous. Why couldn't you live in air made of carbon dioxide?

2. Is the air that we breathe composed entirely of oxygen?

3. A man starts to work in a garage while the engine of his car is running. The wind blows the garage door shut. Why is the man in great danger of being asphyxiated (as·fĭk'sĭ·āt'ĕd), or suffocated?

WORDS FOR THIS CHAPTER

Composition (kŏm'pȯ·zĭsh'*ŭ*n). The substances of which a thing is made up or composed.

Helium (hē'lĭ·*ŭ*m). From the Greek word for sun. A very light element found in the air in small quantities. It was first discovered in the sun.

Argon (är'gŏn). From the Greek word meaning *lazy*. A very inactive element found in the air.

Neon (nē'ŏn). An element found in the air. There is only about one part of it in from 20,000 to 40,000 parts of air.

Nitrogen (nī'trȯ·jĕn). An element which forms nearly four-fifths of the bulk of the air.

Dilute (dĭ·lūt'). Reduced in strength, as by the addition of water.

Tungsten (tŭng'stĕn). An element of the chromium family, widely used in electric-light filaments.

CHAPTER 9 ——————— UNIT 4

What Is Air?

139. What is the gas which we call air? You have already learned that air is real — that it has weight — that it exerts force or pressure in all directions — and that we live at the bottom of a vast ocean of it. But you will be interested, too, in learning what air is and of what it is made up, or composed. You may remember that Aristotle considered it one of his four elements. He was not an experimenter, and he made only a poor guess. His influence as a philosopher was so great, however, that his ideas were accepted for centuries.

No one had any good ideas about the *composition* of air until about the time of the American Revolution. About that time some scientists in England, in France, and in Sweden were at work performing experiments which gave to the world real knowledge of some of the gases which are mixed to form our atmosphere. It was then that oxygen was discovered in the air. Other gases, too, were found to be present in air.

Colorless gases are hard to find, and even at that time the experimenters did not find all the elements that are present in the air. *Helium,* for example, was first discovered in the sun before it was found to be present in the air of this earth in extremely small quantities. *Argon* was not found until more than one hundred years after the discovery of oxygen. It is used in some electric-light bulbs. Three other rare elements, present in the air, were not discovered until the year 1900. *Neon,* which is one of them, is used in the brilliant advertising signs one commonly sees. In addition to being colorless, these gases are all odorless and tasteless.

140. How was oxygen discovered? Joseph Priestley, an Englishman, was a minister and a scientist. He seems to have been more successful in his scientific work than he was in his ministry. Because his religious ideas did not agree with the ideas of those with whom he worked, he was forced to leave England. He went to Pennsylvania and settled near Philadelphia. [See Fig. 9–1.]

Let us repeat Priestley's experiment in which he prepared oxygen, using apparatus a little more modern. In 1774, Priestley used a large glass lens, or a burning glass, to focus

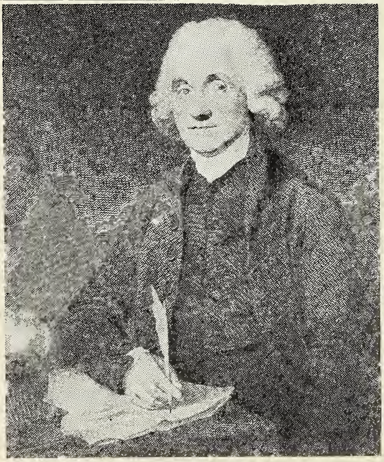


FIG. 9–1. Joseph Priestley was the discoverer of oxygen, which was later named by Lavoisier. He performed many experiments with gases. Priestley was born in England, where he lived and studied until 1794, when he came to live in Pennsylvania. His home at Northumberland is preserved and is often visited by scientists.

the heat rays from the sun upon a red powder which chemists call *oxide of mercury*. We shall use a gas burner invented by a German chemist, Robert Wilhelm Bunsen.

In a hard glass test tube we shall place a few grams of the red powder, which may be called the ash formed by burning mercury. As we heat the tube rather strongly, we notice that the powder loses its red color, and that tiny drops of a shiny liquid – mercury – can be seen collecting on the inside walls of the tube. Nothing else can be seen inside the tube, but if we extinguish the flame from a blazing splint, leaving only a *glowing coal* at the end of the splint, and push it gently inside the tube, the *live coal bursts into flame*. There must have been a colorless gas there which united with the glowing coal to make it burn.

Priestley called this gas which he discovered, " perfect air " or " very active air." He caught a live mouse and put it in a jar of the " perfect air " which he had prepared. He found that the mouse became very active and skipped about in a lively manner. He was so delighted to notice that the mouse showed so much activity that he decided to inhale some of the gas for himself. Priestley wrote that his breast seemed peculiarly light and free as he breathed this " very active air." A Frenchman by the name of Lavoisier (lȧ′vwȧ′zyā′) gave the name " oxygen " to the gas which Priestley discovered. He also proved that it is present in ordinary air, forming a little more than one-fifth of the entire bulk of the air.

141. How can we prepare enough oxygen to test the gas? Let us first set up an apparatus like that shown in Figure 9–2. We then make a mixture containing five grams of a white crystalline solid called *potassium chlorate* (pȯ·tăs′ĭ·ŭm klō′rāt), and three grams of a black powder called *manganese dioxide* (măng′gȧ·nēs dī·ŏk′sīd). Next we pour the mixture into the test tube. A bent glass tube fits the stopper tightly

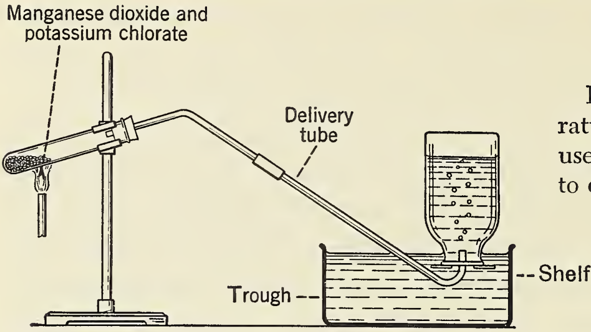
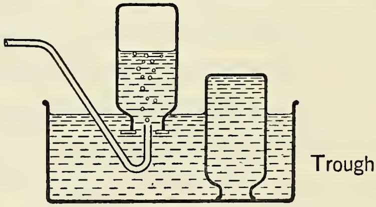


FIG. 9–2. Apparatus which may be used to prepare and to collect oxygen.

and a rubber tube through which the gas can flow freely is attached to the bent glass tube. The pan, or trough, in which the bottles are placed was invented by Priestley. It should be filled with enough water to cover the shelf. Each bottle is filled with water, covered with a glass plate, and turned upside down in the trough, and then the plate removed. [See Fig. 9–3.] The water will not run out. One of

FIG. 9–3. In the laboratory, gases may be collected by water displacement.



the bottles, with its mouth kept under water, is moved to the shelf of the trough, directly over a large hole. When the mixture in the test tube is heated, oxygen gas is driven off, and it bubbles up through the water into the bottle. It there crowds the water out of the bottle, because two things cannot occupy the same place at the same time. When one bottle is full of gas, we place a glass plate over its mouth and remove it from the trough. We let it stand covered on the desk while we proceed to fill other bottles in the same way.

142. What can we learn about oxygen? First you observe that the gas is colorless. If we place one of the bottles on the desk, mouth upward, and remove the glass plate, we may inhale some of it. We find that *pure oxygen* has no odor and no taste, although some *impurities* present may give it a sharp odor. A glowing splint thrust into a bottle of the gas bursts into flame. *This test serves to prove that the gas is oxygen.*

By using a pair of iron tweezers, we may hold a splinter of charcoal in the flame of the burner until it glows. When the charcoal is lowered into a bottle of oxygen gas, it burns much more vigorously. Sulfur, too, burns more vigorously in oxygen than it does in air. [See Fig. 9–4.]

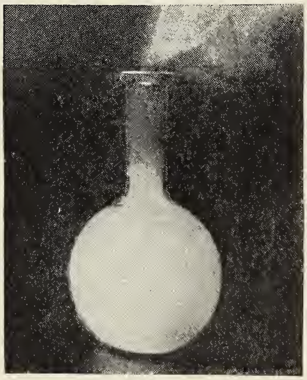


FIG. 9–4. Phosphorus, which means *light bearer,* burns in oxygen with terrific heat. The particles of the oxide of phosphorus which are formed are heated white hot. Because the whole flask glows, the device was at one time called the "philosopher's lamp." (*Photo by Wettlin*)

Thus we find that substances burn more rapidly in oxygen than they do in air. It is possible, too, to show that some substances which do not burn in air will burn rapidly in oxygen. Let us pour enough water into a bottle of oxygen gas to fill it about one-fifth full. We may then make a little twist of steel wool, hold it with the tweezers, heat it slightly in the flame of the burner, and then quickly thrust it into the bottle of oxygen to which the water was added. We see that the steel wool burns rapidly, giving off sparks much like those of

a Fourth of July sparkler. The heat is terrific, and some of the iron may be hot enough to break the bottle, since it may melt and fall through the water. Is it strange that Priestley called this wonderful gas " very perfect air "?

143. Is oxygen a part of ordinary air? Priestley never proved that oxygen, or what he called " very active air," is merely a part of the air we breathe. That proof was furnished by the Frenchman, Lavoisier, who first guessed the truth, and then made an experiment to make certain that his guess was correct.

Lavoisier heated some mercury *very slightly* in ordinary air and found that the red powder, oxide of mercury, was formed. The mercury must have combined with something that was in the air to make the red powder. When Lavoisier heated the red powder *more strongly*, he found that it gave off oxygen, which of course it must have taken from the air.

In a similar experiment, he heated some mercury in a *measured volume* of air for twelve days. He found that a little more than 20 per cent of the air would combine with the mercury to form the red powder. [See Fig. 9–5.] He concluded that it must have used up all the oxygen in the air, because nearly 80 per cent of the bulk of the air refused to combine with the mercury, no matter how long he contin-

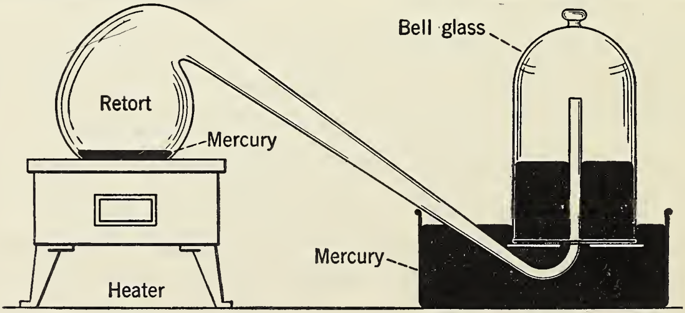


Fig. 9–5. Mercury in the retort unites with the oxygen from the bell glass.

ued to heat it. Other persons, too, have performed experiments which show that approximately one-fifth of ordinary air is oxygen gas.

144. **How is oxygen necessary to life?** You could probably live for a week or more without solid food. You could possibly live two or three days without water, but you could not live more than a few minutes without oxygen. An English chemist by the name of Rutherford removed all the oxygen from some air and then put a live mouse in the gases which were left. In just a few minutes the mouse died. The mouse suffocated because there was no oxygen present in the air. If you recall how pure oxygen stimulated the mouse in Priestley's experiment, you can readily understand that oxygen is necessary to life. It may justly be called the *life-continuing element.*

It is the oxygen in the air that all animals use to keep them alive. Even animals which live in water must have a supply of oxygen. The turtle comes to the surface occasionally to inhale air containing oxygen. Fish that live in water take oxygen from the air that is dissolved in the water. If you watch a goldfish in an aquarium, you will see the water being taken in through the mouth. This water is then passed out through the gills. As the water flows over the blood tubes spread out in the gills of a fish, the oxygen leaves the water and passes through the thin walls of the blood tubes into the blood of the fish. If you boil water, the air dissolved in it is driven off. Even if such water were cooled, a fish placed in it would soon die from oxygen starvation, unless the water had stood long enough to take in more oxygen from the air. [See Fig. 9–6.]

145. **What element in the air is most abundant?** Almost four-fifths of the bulk of air is a colorless, odorless, tasteless gas known as *nitrogen.* No fire can burn in pure nitrogen,

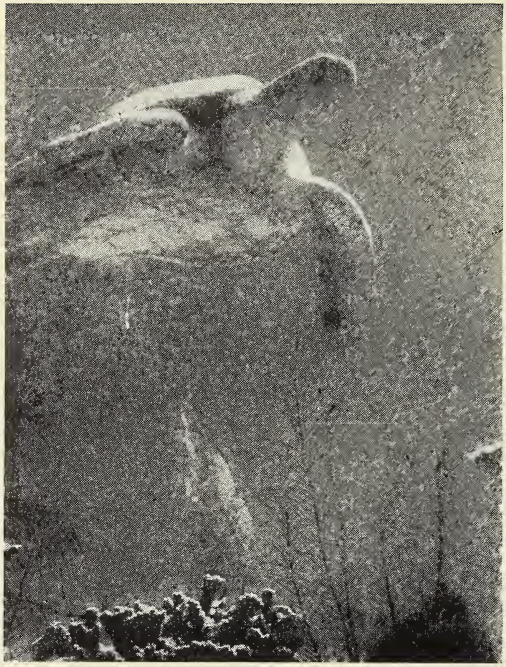


Fig. 9–6. The turtle rises to the surface occasionally to get more oxygen. The one pictured here, a green turtle, weighs 235 pounds. Turtles have lungs, rather than gills. How long can you stay under water safely? Can you find out why a turtle can stay under water for a fairly long time? (*Courtesy Marineland Studios*)

and animals would suffocate if the air were pure nitrogen. Since it does not seem to be good for animals to breathe pure oxygen for a very long time, and since it would be almost impossible to put out a fire if the air were pure oxygen, the nitrogen seems to serve an important purpose when it *dilutes* the oxygen of the air.

Nitrogen is a very important element since it is needed in the growth of plants. It is interesting to learn that most plants cannot take nitrogen directly from the air. It must be combined with some other element, or with other elements. Such compounds of nitrogen dissolve in the water of the soil and are then taken in by the roots of plants. Most fertilizers added to the soil contain compounds of nitrogen for the use of plants. Such plants as clover, peas, and beans have little *knots,* or *nodules* (nŏd′ūlz) on their roots. Such

nodules contain bacteria which take nitrogen from the air and make compounds of it, thus enriching the soil. It is a very strange world. Plants live with their leaves immersed in air which is almost 80 per cent nitrogen, and they cannot use that nitrogen unless it is combined with something which makes it soluble in water so that it can be taken in by the roots. We live and breathe in air which is only a little more than 20 per cent oxygen, but we cannot live in water, which contains more than 88 per cent of oxygen by weight. In water the oxygen is firmly united with hydrogen, and we cannot use it in that form for breathing. Nor can we breathe the oxygen absorbed by the water, as the fish breathe it.

146. How can you get some nearly pure nitrogen? When Lavoisier heated mercury, he kept taking more and more oxygen from the air until there was none left. Several other substances may be heated or burned in air to remove the oxygen. After all the oxygen has been taken out, a mixture of gases is left, but that mixture is about 98 per cent nitrogen.

If we put air under a very great pressure and then let it expand rapidly, the air will be decidedly cooled. Compressing a gas heats it, and letting it expand cools it. If we continue to compress air and then cool it, we may finally change it into a liquid. Liquid air is colorless, and it can be poured like water. It resembles water, too. It is *extremely cold.* If poured into an open pan, it boils vigorously, but its boiling point is nearly 190 Centigrade degrees below zero. That is more than 300 Fahrenheit degrees below zero. When liquid air boils away, nearly pure nitrogen gas boils away first, because nitrogen molecules move faster than oxygen molecules. The nitrogen can be collected as it evaporates. Later, after the nitrogen has all boiled away, nearly pure oxygen can be collected.

147. Is carbon dioxide present in air? Joseph Black, a Scotch chemist, first learned that the air contains *carbon dioxide.* He called the gas *fixed air.* The amount present in the air is not very great, but there is always some carbon dioxide in ordinary air, and it is very useful too. In 10,000 quarts of air, there are about four quarts of carbon dioxide. Just how important so small an amount is we shall learn when we take up the study of green plants, and learn how they use carbon dioxide to make sugar and starch.

148. How can you prepare some carbon dioxide to study? Fuels such as coal, oil, and gas contain much carbon. Every time we burn anything that has the element carbon in it, we are preparing carbon dioxide. The carbon dioxide prepared by burning fuels mixes with the air, however, and one cannot study its behavior. Let us put into a wide-mouthed bottle three or four lumps of marble, each about the size of a hazelnut or filbert. [See Fig. 9–7.] Then we shall

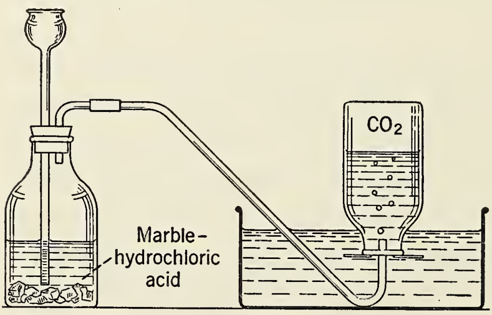


FIG. 9–7. Such an apparatus may be used to prepare carbon dioxide. Some of the carbon dioxide dissolves in the water when gas is collected in this manner.

close the bottle with a rubber stopper which is fitted with a thistle tube and a glass delivery tube. The thistle tube is used so that we may conveniently pour water or acid into the bottle. Let us then pour a half test tube of water through the thistle tube. Next we may add enough *hydrochloric acid* to start a rather vigorous production of gas. We collected

oxygen gas by letting it displace water. In the same way we collect two bottles of carbon-dioxide gas, which is set free when the acid reacts with the marble. The carbon-dioxide gas escapes from the marble with much foaming.

149. What can we learn about carbon dioxide? Pure carbon dioxide has no color and little or no odor. When the gas is dissolved in water, it gives to the water a slightly pungent taste such as we get from plain soda water, which is really carbon dioxide dissolved in water. Carbon dioxide is considerably denser than either oxygen or nitrogen. In fact, we can pour it downward from one vessel into another, just as we pour water. It is not poisonous, but animals will suffocate in an atmosphere of carbon dioxide, just as they do in nitrogen or in air which has been deprived of its oxygen.

Into one of the bottles which we collected let us thrust a *blazing* splint. The flame is quickly extinguished. Carbon dioxide does not burn, and substances will not burn in carbon dioxide. In the bottom of a beaker let us put a short piece of candle and light it. Next we pour down into the

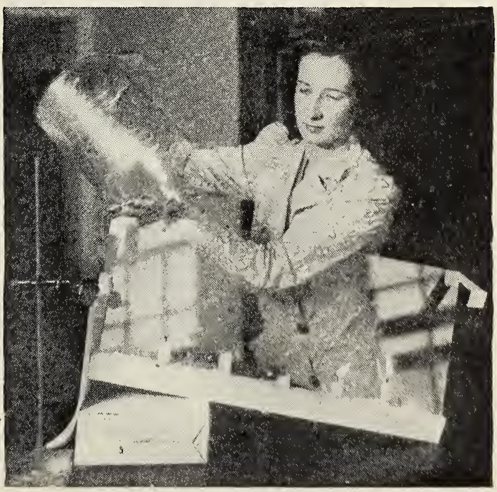


FIG. 9.–8. As carbon dioxide is poured from the large bottle, it flows down the inside of the glass trough, extinguishing each candle in turn. This experiment proves two things. Carbon dioxide is denser than air; and it can be poured downward. Therefore it can be used to extinguish flames. (*Photo by Wettlin*)

beaker the carbon dioxide from one of the bottles which we collected. As the dense gas sinks down into the beaker, the candle flame is extinguished. What two facts does this experiment show about carbon dioxide gas? [See Fig. 9–8.] One very efficient type of fire extinguisher uses liquid carbon dioxide.

150. How can we test for the presence of carbon dioxide? Let us first pour a little more acid into the bottle containing the pieces of marble in order to start again the production of carbon dioxide. This time we shall let the gas bubble through a test tube about one-third full of limewater. In a short time the limewater becomes milky in appearance. Because a small amount of carbon dioxide added to limewater always turns it milky in color, *we may test for the presence of carbon dioxide by bubbling it through limewater.*

Try the following experiment. Use a glass tube about eight inches long and blow your breath through a test tube a little less than half full of limewater. In a few minutes the limewater becomes milky. This simple experiment proves that there is carbon dioxide present in the air that you breathe out or exhale.

151. What other gases are found in air? In our study of the water cycle we learned that the air always contains some water vapor. Of course the amount present varies in different places, and it also varies in any one place at different times. It is usually greater when the temperature is high than when the temperature is low. It is greater over the oceans or near them than it is in desert regions and in the interior of large continents. [See Fig. 9–9.]

Almost one per cent of the air is *argon,* the gas which is used for filling some electric-light bulbs. It is used because it will not do anything at all. It does not combine with the metal *tungsten* used to make the filament. It is useful be-

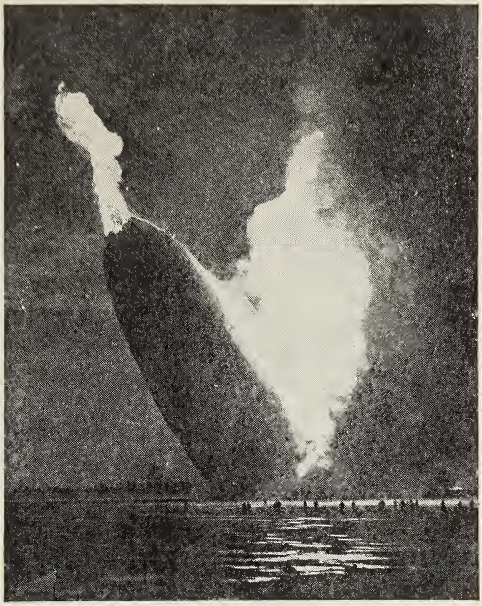


FIG. 9–9. This picture was taken at almost the same second that the Hindenburg exploded. It shows the giant dirigible just as the second and third explosions sent the airship crashing down to earth. If this dirigible had been filled with helium, such an accident could not have happened. You may wonder why helium was not used. The chief reason is that helium is not found in quantity outside the United States. (*Press Association, Inc.*)

cause it gets in the way of the tungsten molecules that are trying to evaporate. Thus it keeps them from collecting on the walls of the bulb and making it dark-colored.

Helium, which is present in the air in very small quantities, is used in filling balloons. Since it does not burn, it will not set fire to the balloon or dirigible. It is denser than hydrogen, and for that reason it is only about 92 per cent as efficient as hydrogen for lifting balloons. [See Figs. 9–10 and 9–11.]

Neon is one of three rare gases which were discovered in the air in 1900. It is widely used in making neon advertising signs. When electricity flows in the gas, it gives a brilliant light. It is probably the cheapest type of light that can be used for advertising purposes.

152. How do impurities get into the air? When we turn on the gas in a stove, a little escapes into the air before we can light it. The poisonous gas, *carbon monoxide,* escapes

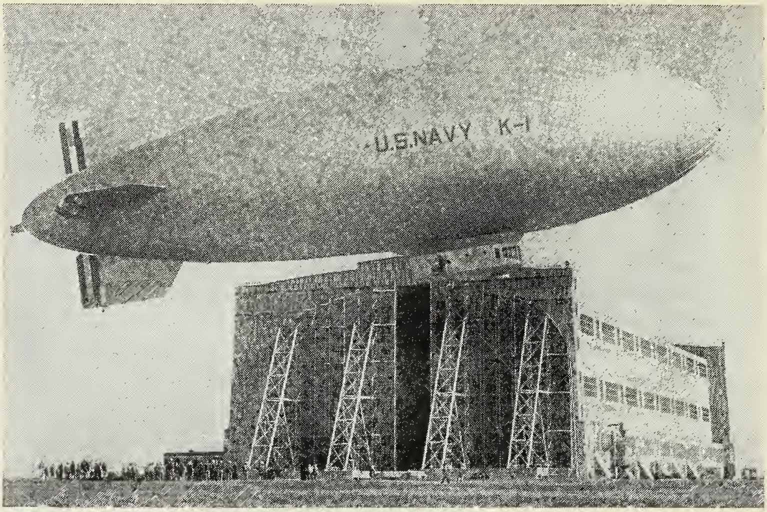


FIG. 9–10. One of the Navy airships in front of the hanger. Its gas bags contain helium gas. (*Official photograph, U. S. Navy*)

into the air from the exhaust pipes of automobiles. Some of this gas may also escape into the air from our chimneys when we burn oil, coal, or coke. It is likely to be formed when coal fires are banked for the night. If the furnace door is left open, this poisonous gas may find its way to the living room

FIG. 9–11. Have you ever seen the inside of a Navy balloon? You can cook just as good a meal as you eat at home in the kitchen of one of these dirigibles. The kitchen and control room are located in the structure attached to the bottom of the airship. Do you know where the gas is kept in dirigibles? (*Courtesy Newark Sunday Call*)

or the sleeping rooms of our houses. It gets into our houses, too, if the joints in the smoke pipe are not sufficiently tight. Some gases used for stoves contain much carbon monoxide, but natural gas is a fuel that is free from it.

Partly burned gasoline sometimes escapes into the air from the exhaust pipe of an automobile. [See Fig. 9–12.] Ammonia gas escapes into the air when ammonia bottles are left unstoppered. Many gases escape from the chimneys of factories. Both gases and dust may injure near-by vegetation.

Particles of carbon and soot escape into the air when soft coal is burned. The air over industrial cities may be dark with soot particles that are being belched forth from many chimneys. From volcanoes, from duststorms, and from outdoor fires, also, particles of fine dust get into the air.

All the substances mentioned in this section, whether gases or solids, are known as impurities, when they are found in the atmosphere.

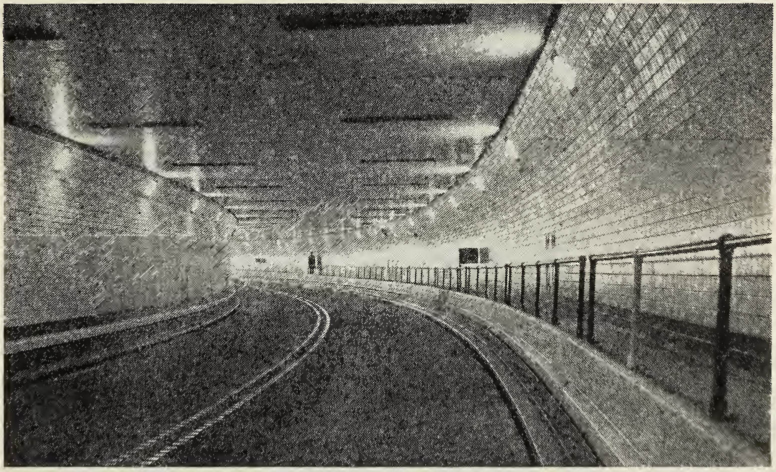


Fig. 9–12. The Lincoln Tunnel was built under the Hudson River. Thousands of automobiles pass through the Lincoln and the Holland Tunnels which connect New York City with New Jersey. The ventilation is excellent. (*Courtesy The Port of New York Authority*)

QUESTIONS

1. Why do men flying at high altitudes need to carry tanks or cylinders of compressed oxygen gas?

2. Make a list of the gases that are present in ordinary air.

3. What arguments can you give for the statement that oxygen is the most important gas known?

4. How would you test a gas to prove that it is oxygen?

5. Why is it dangerous to breathe air that contains even a small percentage of carbon monoxide?

6. In what different ways is carbon-monoxide gas likely to get into the air?

7. Figure 9–12 shows a view of the Lincoln Tunnel under the Hudson River. Thirty-two large electric fans blow air through the tunnel to secure ventilation. Why are they necessary?

8. Does the small per cent of carbon dioxide present in air make it unfit to breathe? Explain.

9. How can we test a gas to show that it contains carbon dioxide?

10. From what you have learned about air, do you think that it is an element or a mixture?

SOME THINGS FOR YOU TO DO

1. Read about the destruction of the airship *Hindenburg* at Lakehurst, New Jersey in 1937. Do you think the accident would have happened if the airship had been filled with helium gas? Do you know why it was not filled with helium gas?

2. If you have a chemical set at home, prepare a little oxygen and burn a little sulfur in it. Also burn some charcoal. Use a glowing splint to test for the presence of oxygen.

3. Test your breath to see whether you exhale carbon dioxide. Use a straw to blow your breath through some limewater.

4. Prepare a bottle of carbon dioxide. See whether you can pour it downward to extinguish a candle flame.

Fire Is a Good Servant but a Bad Master

HAVE you ever known anyone who did not like to sit in front of a campfire or a good fire in a fireplace and watch the flames? Is it strange that ignorant people have worshiped fire?

Have you ever wondered just what happens when wood or other fuel burns? In the past many attempts were made to explain the nature of fire. The ancient Greeks had a legend about the hero Prometheus, who was supposed to have stolen fire from the gods and brought it down to earth for mortals. The ancient Romans believed that their god Vulcan worked at the forge and taught man to use fire.

About the end of the seventeenth century a German chemist named Stahl explained fire by saying that a fuel such as wood burns because it contains a substance that he called "phlogiston" (flō̇·jĭs′tŏn). According to his theory, gases

like nitrogen and carbon dioxide do not burn, because they contain no phlogiston. Hydrogen was supposed to contain phlogiston. Stahl's theory was believed for about a century.

It was not Priestley, the discoverer of oxygen, who gave us the true explanation of fire. It was Lavoisier who gave us the explanation which we now feel sure is the correct one. It was Lavoisier, also, who gave the name *oxygen* to Priestley's "perfect air."

In this unit we shall learn what conditions are necessary before we can have a fire. We shall learn what actually happens when a piece of wood or a lump of coal burns. We shall learn, too, what conditions are necessary for putting out a fire, and what methods are used by modern fire fighters.

Think about these!

1. What is fire, and where does it come from?
2. Why have men worshiped fire? How do animals behave near a fire?
3. How does a fire start? How can it be extinguished?
4. Can a fire start itself, without the application of heat to the fuel?

Words for this chapter

Burning. The uniting of oxygen with some other substance so rapidly that both light and heat are produced.

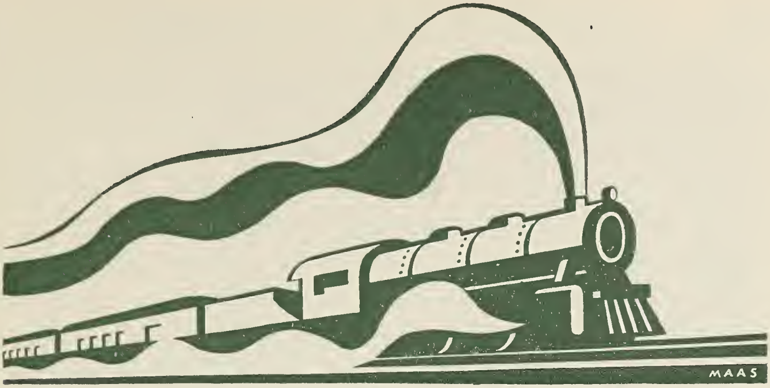
Combustion. Act of burning.

Kindling temperature. The *lowest* temperature at which a substance begins to burn.

Friction. The resistance to motion. Friction causes heat.

Tinder. Material of low kindling temperature.

Spontaneous (spŏn·tā′nė·ŭs). From the Latin word *sponte,* meaning *free will.* Acting of its own accord, without apparent outside urge or aid.



CHAPTER 10 _______________ UNIT 5

What Is Fire?

153. What were some of the old ideas about fire? If you sit before an open fire and watch the flames playing, you may become curious to know just what *burning* is. [See Fig. 10–1.] For centuries men wondered about that question without arriving at the correct answer. The Greeks and Romans, with all their learning and civilization, failed to find the answer. Each one pictured a hero who had stolen fire from the gods and brought it down to the earth for the use of mortals. In mythology we read such stories, and we also learn how the gods punished heroes who were guilty of such theft. Perhaps you remember some of the old legends about fire.

We read in history of many races who were fire worshipers. The warriors of savage Indian tribes danced around huge bonfires to work themselves into a frenzy before going into battle. Some animals are attracted by fire; many are awed by it. A camper in the wilds where there are ferocious ani-

mals is careful to keep his campfire burning. In the still night he may awake to see the shining eyes of some wild beast crouched in the shadows beyond his campfire.

No one knows who discovered fire or how such a discovery was made. It may possibly have been a flash of lightning which struck a pine tree and ignited its needles. The first fire on the earth may have started from hot lava from some volcano. No matter what its origin, we may be certain that the first man to see fire must have been filled with awe and wonder. For an explanation of the nature of fire, we must turn to modern science.

154. What happens when wood burns? When we repeated Priestley's experiment, we found that a glowing splinter would burst into flame in oxygen gas. It was Lavoisier who found that heated mercury will continue to take oxygen from the air until it has used up all the oxygen that was present. Mercury would not combine with the gas which was left, and *wood would not burn in the air from which the*

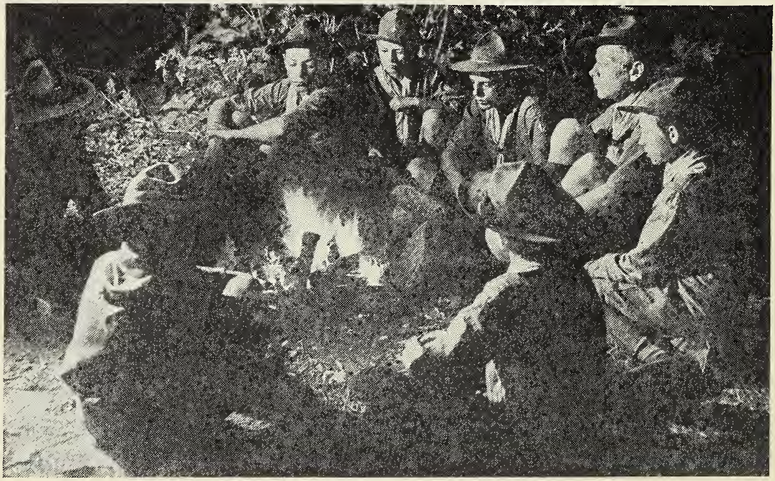


FIG. 10–1. The flames of an open fire add greatly to the pleasure of camping. (*Courtesy Boy Scouts of America – Paul Parker Photo*)

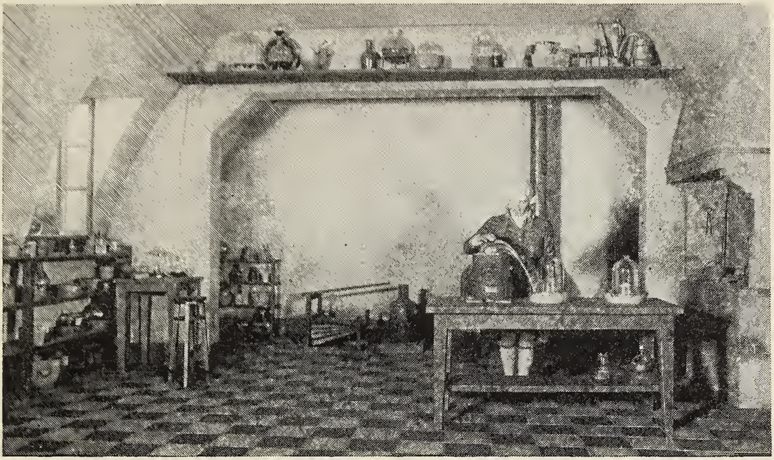


FIG. 10–2. Lavoisier working in his laboratory. He named oxygen and hydrogen and explained what happens when fuel burns. He lived at the time of the Revolutionary War. (*Courtesy Union Carbide and Carbon Corp.*)

oxygen was removed. From such experiments, it seems certain that ordinary burning or *combustion* cannot take place without oxygen. [See Fig. 10–2.]

Lavoisier's experiments showed that ordinary burning is a process in which the oxygen of the air unites with some or all of the elements of the burning substance. For example, wood contains carbon, hydrogen, and some other elements. When wood burns, the oxygen from the air unites with the carbon from the wood, and one product formed is carbon dioxide. The hydrogen of the wood unites with the oxygen from the air, and water is formed as another product. Any fuel that contains carbon forms carbon dioxide as it burns. Gasoline contains both carbon and hydrogen. Hence both carbon dioxide and water vapor escape from the exhaust of an automobile when the engine is running. On a cold day, you can see a cloud of waterdrops as the vapor condenses

upon striking the cold air at the end of the exhaust pipe.

In the process of burning, the union of the oxygen and fuel occurs so rapidly that both light and heat are given off. The burning of a fuel gives energy in the form of heat and also in the form of light. Energy is defined as the *capacity for doing work.* In producing steam, for example, the heat from the burning fuel is used to boil the water, and the resulting steam drives the steam engine. The heat from the mixture of gasoline vapor and air, which explodes in the cylinders of a gas engine, supplies the energy used for driving the engine.

155. How does oxidation occur? When mercury is heated in air or in pure oxygen, it unites with the oxygen and forms a red powder which chemists call *mercuric* (mûr·kū′-rĭk) *oxide.* If tin is heated in a similar manner, it unites with the oxygen and forms a white powder which is called *tin oxide.* Zinc, when heated in air, unites with the oxygen and forms a white powder known as *zinc oxide.* If we heat a sheet of copper in air, the copper unites with the oxygen and forms a black scale known as *copper oxide.* Blacksmith shops are not so common as they were when Longfellow wrote the poem "The Village Blacksmith," but possibly you can still find one in your neighborhood. If so, you will find it fascinating to watch the sparks which fly from the white-hot iron which the blacksmith pounds on his anvil. Examine one of those sparks after it has cooled. You will find that it has a blue-black color. It is *iron oxide,* and it was formed by the union of the oxygen from the air with the hot iron. All these experiments are examples of the process of oxidation, in which oxygen unites with some other substance.

156. How do slow oxidation and rapid oxidation differ? Oxygen may unite with metals slowly over a period of months or years. No light is given off in such cases, and the heat is given off so slowly that it cannot be noticed unless accurate

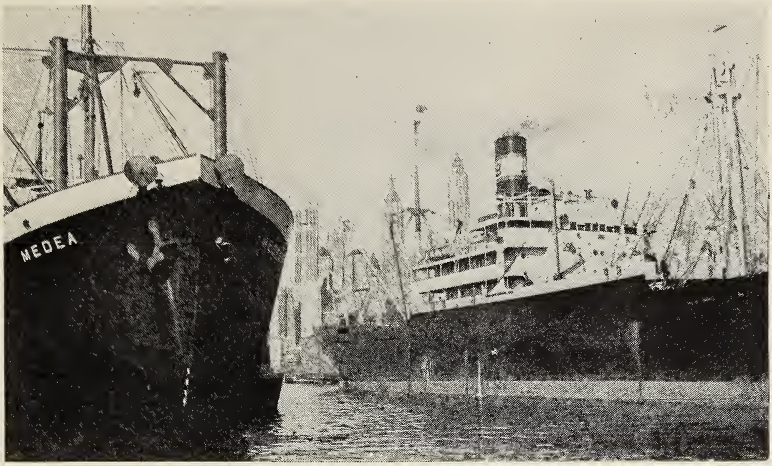


Fig. 10–3. Slow oxidation is continuously taking place on such ocean-going freighters as these. If rapid oxidation were taking place here, how would the picture be different? (*Courtesy John L. Lochhead*)

measurements are made. [See Fig. 10–3.] This is called *slow oxidation.* Heat is actually given off in such cases, however, and the total amount is the same as it would be if the same metals were oxidized rapidly in only a few minutes.

Slow oxidation is of the greatest importance. When we breathe, we take air into our lungs. The oxygen from the inhaled air finds its way into our blood and then into the cells of the body, where it unites slowly with the carbon and hydrogen that is present in all our foodstuffs. The energy produced by such *slow oxidation* keeps our bodies warm. It also supplies us with the physical energy which we need to do our work from day to day.

Rapid oxidation produces both *light and noticeable heat.* [See Fig. 10–4.] The process does not differ from ordinary rusting or oxidation, except in speed. When a piece of wood burns, its carbon and hydrogen unite with the oxy-

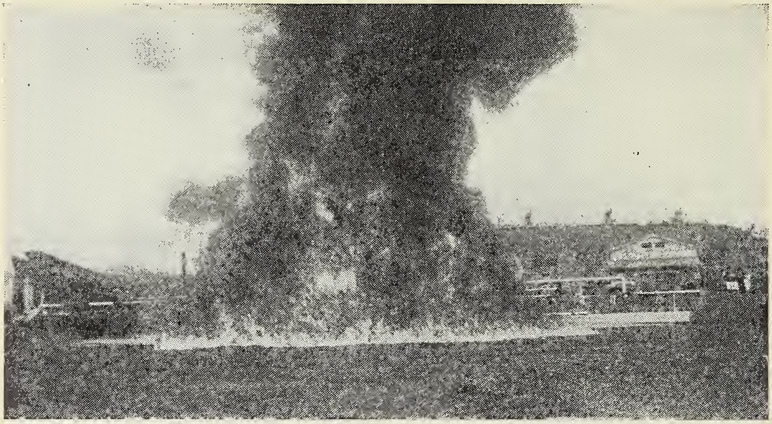


FIG. 10–4. What characteristics of rapid oxidation do you see in this picture? (*Courtesy Pyrene Manufacturing Co.*)

gen in the air, and the process is complete in a short time.

157. What three things are needed for combustion? We cannot have a fire without these three things:

a) *Some material that will burn.* We learn by experience that soil, water, and rocks do not burn. Before we can have a fire, we must have some combustible material. Wood, coal, gas, kerosene, gasoline, and alcohol are examples of substances that burn readily. They all contain carbon, sometimes seen as a black element, when meat and vegetables scorch, or when wood is charred. Nearly all substances that burn readily also contain hydrogen, the light, colorless gas which unites with oxygen in burning, and forms water. We conclude, therefore, that we cannot start a fire unless we have a supply of fuel.

b) *A supply of oxygen.* If we lay a fire by placing some paper and wood on the furnace grate, and then try to start a fire with all the drafts closed, we shall not succeed. There must be an opportunity for air to get in through the draft to supply the oxygen which unites with the fuel as it burns. We

may hold a blazing stick in a bottle of air. The fire soon goes out, because all the oxygen has been used up. It is possible to perform other experiments to prove that ordinary burning cannot take place without air which contains oxygen.

c) *Fuel that has been heated.* The desk at which you are sitting is probably made of wood. It is surrounded by air. Two conditions necessary for a fire have been met, but still the desk does not burn. One other thing is necessary.

You may put wood in your furnace and open the drafts for air to enter, but it does not burn until you have heated the wood to a certain temperature known as its *kindling temperature.* The lowest temperature to which wood must be heated before it begins to burn is called its kindling temperature. The kindling temperature varies with the kind of fuel.

158. How can the kindling temperature be reached? Boy Scouts are taught to use fire sticks. [See Fig. 10–5.]

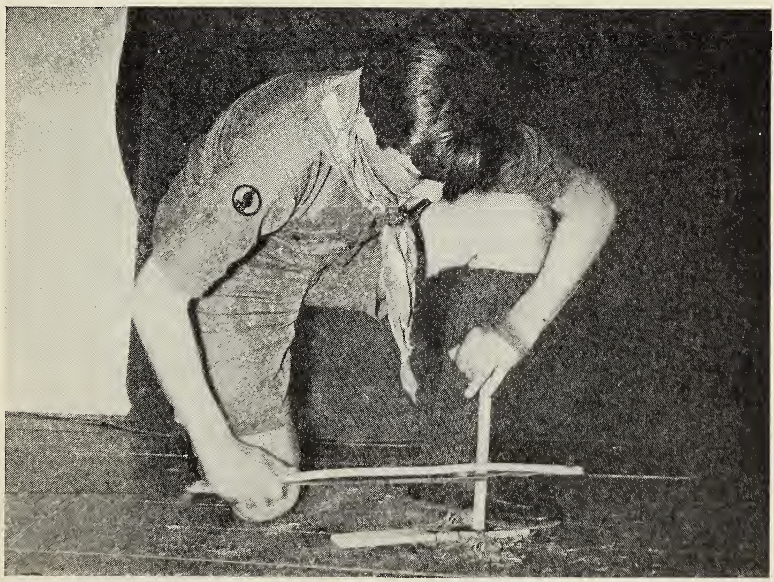


FIG. 10–5. Why do Boy Scouts today learn how to start a fire by the use of fire sticks? (*Courtesy Boy Scouts of America*)

The *friction* caused by moving one stick rapidly over another causes enough heat to warm the stick up to its kindling temperature. The Indians, too, are said to have used this method of starting fires. You burn your hands by the heat of friction if you slide down a long rope, gripping it too tightly as you slide. The heat of friction sometimes sets fire to the brake linings of an automobile if the driver keeps the brakes applied too long when going down a hill or mountain.

Our forefathers used flint and *tinder* for starting fires. The flint is struck to produce a spark, and the spark kindles the tinder. In order to fire the rifles used in the Revolutionary War, a piece of flint was used. When the hammer struck the flint, a spark was produced. [See Fig. 10–6.] The spark was hot enough to ignite the gunpowder, which has a low kindling temperature.

Matches are now in common use. The tip of the match head is made of some material which has a low kindling tem-

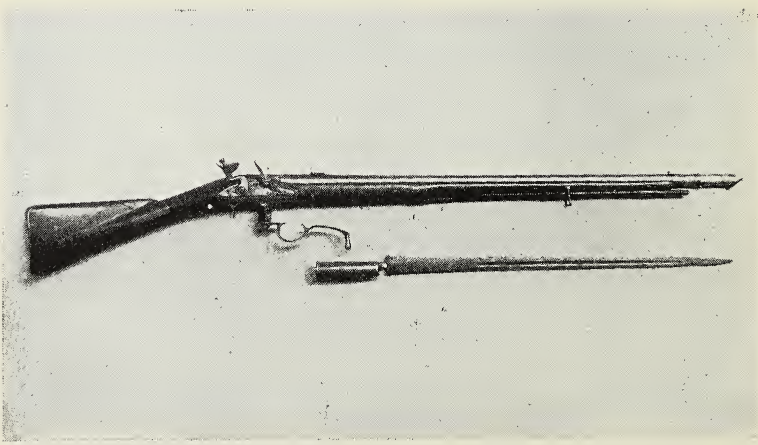
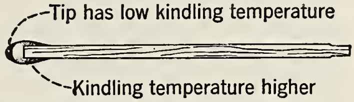


Fig. 10–6. An old muzzle-loading rifle. The charge is ignited by a spark made by the hammer striking a piece of flint. (*Smithsonian Institution*)

perature. When the head of the match is rubbed across some rough surface, it is heated by friction to the kindling temperature of that substance used to make the match head. As the head of the match burns, it heats the wood of the match stick to its kindling temperature. [See Fig. 10–7.]

FIG. 10–7. The tip of the match head has a low kindling temperature.



The blazing match is then applied to some paper, shavings, or tinder until they in turn are heated to their respective kindling points. As they burn, they may kindle some wood or charcoal, which then becomes hot enough as it burns to kindle the coal. This is the principle now used in starting fires.

159. How can one put out a fire? Since three conditions must be met before we can have a fire, we may remove any one of the three in order to extinguish the fire. Naturally a fire cannot continue to burn if we remove the combustible material. If you saw the motion picture *San Francisco* or *Chicago,* you observed men dynamiting large buildings in whole city blocks, to bring down combustible material and prevent the fire from spreading over miles of the city. Firemen sometimes dynamite buildings in one or more city blocks in order to check a large city fire. For the same purpose, men cut away timber and underbrush along a strip several feet wide, thus creating what is called a *fire stop.* [See Fig. 10–8.] Leaves and dried grass may be removed, too, to keep fires from spreading. Sometimes the land on both sides of a railroad track is plowed to prevent the spread of fires which might be caused by sparks from the engine. Forest fires are frequently checked by starting a backfire or check fire in front of the big fire. When the big fire reaches the burned-over area, it goes out for lack of fuel.

FIG. 10–8. Even if a forest fire occurs on either side of the land which has been denuded of trees, it is not likely to spread to the opposite side of the fire stop. (*Photo by U. S. Forest Service*)

Sometimes it is possible to put out a fire by shutting off the oxygen supply which the fire needs in order to burn. Water thrown on a fire does two things: (*a*) it evaporates and forms a cloud of vapor, which rises around the fire and tends to shut off the oxygen, and (*b*) it tends to cool the burning material below its kindling temperature. [See Fig. 10–9.]

If your clothing catches fire, you should lie down on the floor and roll yourself up in a rug or blanket. In that way you would smother the fire by shutting off the oxygen in the air. Running out into the open air would be the worst thing

FIG. 10–9. Do you know when it is unsafe to use water in trying to put out a fire? What precautions should the average family take against fires in and around the home?

you could possibly do if your clothing caught fire. Can you understand why?

Sometimes we put out our furnace fire by adding too much fuel at one time, when the fire is very low. The *cold* coal which is added may cool the dying embers below their kindling point. To put it another way, there is not enough heat in the dying coals to heat the fresh coal up to its kindling temperature. When we extinguish a candle flame by blowing, we merely blow away the hot burning gases and cool them below their kindling point.

To summarize, we may put out a fire by using any one of three general methods: (*a*) by removing the combustible material; (*b*) by shutting out the supply of air or oxygen; or, (*c*) by cooling the burning material below its kindling point.

160. Can a fire start of itself? Do fires ever start without the aid of a match or without being set? Can a fire start *spontaneously?* Yes, it may occur under certain conditions. Painters sometimes spill linseed oil or paint containing linseed oil. They use rags to wipe up the spilled portion or to wipe off the paint they get on their hands. If you were to heap up a pile of such oily rags in a place where there were no drafts, they would probably catch fire in a few hours. In the *first* place, linseed oil is greedy for oxygen. As it oxidizes, or dries slowly, heat is slowly produced. In the *second* place, without drafts the air does not circulate and carry the heat away. In the *third* place, the heat formed by the slow oxidation of the oil raises the temperature more and more until the kindling temperature is reached.

A huge pile of soft coal may contain considerable coal dust. The coal dust from the finely powdered coal has a very large surface compared to its bulk. Oxidation takes place at the surfaces, and it may produce enough heat to warm the coal

dust up to its kindling temperature. For that reason a pile of soft coal may catch fire spontaneously, if it is permitted to stand for some time. Soft coal is often stored under water to prevent such spontaneous combustion. Hay that is not properly dried may begin to burn spontaneously and set fire to the barn in which a large quantity of such hay is stored.

Spontaneous combustion may occur when we have the following conditions:

a) Combustible material which has a rather low kindling temperature, and which oxidizes fairly rapidly at the temperature of the place in which it is stored.

b) Poor circulation of air where the combustible material is stored, so that the heat of oxidation is not carried away and scattered.

Possibly your instructor may demonstrate spontaneous combustion by placing a piece of white phosphorus the size of a very small garden pea upon a square of asbestos board and covering it with a teaspoonful of powdered charcoal or *bone black,* a substance formed by heating bones. The phosphorus has a low kindling temperature. It oxidizes rather rapidly. What is the purpose of the powdered charcoal or bone black?

161. What products are formed by combustion? When we burn coal in a furnace, some solid ash is always left. Some gases are formed, too; they escape up the chimney and out into the air. The ash is formed from the *mineral* matter which was present as an impurity in the coal. If we burn such liquid fuels as gasoline or alcohol, no mineral matter is left. They burn completely. No solid ash is left after the burning of fuel gases. The only products are carbon dioxide and water, and possibly some carbon monoxide.

When the carbon that is present in a fuel – gasoline, for example – unites with the oxygen as it burns, it may form

either carbon dioxide, carbon monoxide, or both. If there is enough oxygen present to burn all the carbon completely, then only carbon dioxide is formed. If there is an insufficient supply of oxygen or an oversupply of fuel, some carbon monoxide is formed too. Both gases are colorless and practically odorless. They escape into the air without our being able to see them at all. Some carbon may remain unburned, and be left as a hard deposit or scale.

The gases which escape up the chimney when wood, coal, oil, or gas is used as a fuel, consist largely of carbon dioxide, carbon monoxide, and water vapor. They form the invisible part of smoke. We sometimes see particles of solid ash, or droplets of liquid, which are carried up with them. Smoke often contains some unburned particles of carbon and soot.

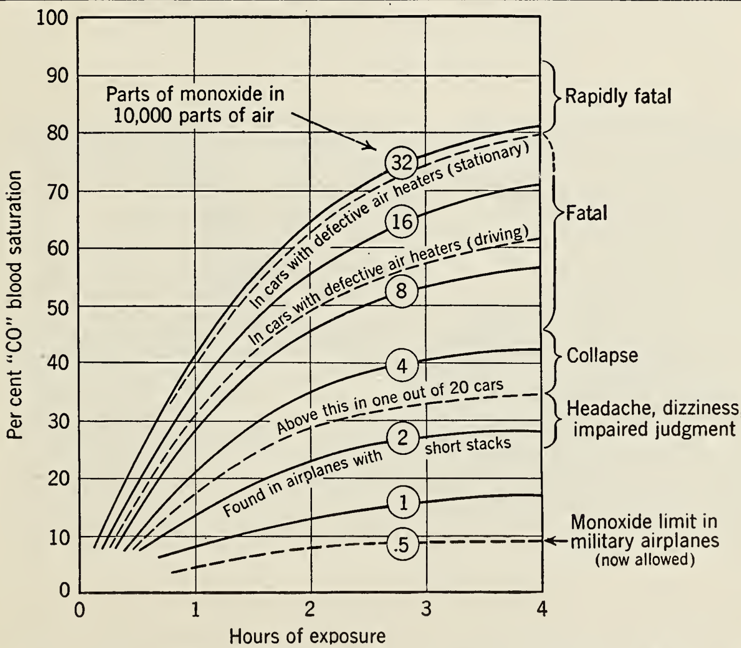


FIG. 10–10. The graph shows the effect of inhaling carbon monoxide (CO). (*From "Scientific American"*)

162. Why is carbon monoxide dangerous? We can never be sure that the air is free from carbon monoxide, because the gas has no color, no odor, and no taste. Only eight parts of carbon monoxide in 10,000 parts of air will prove fatal to a person breathing such air for one or two hours. Increasing the percentage of carbon monoxide in the air shortens the time. [See Fig. 10–10.] Carbon monoxide is especially dangerous because the person who inhales it usually has no warning that he is being poisoned. He collapses suddenly, and is unable to go to a place of safety. He will die unless help is at hand, and even if help comes quickly, he will be revived only with difficulty. Carbon monoxide combines with substances in the red blood cells of the person, and those cells become unable to carry enough oxygen to the cells of the person's body. [See Fig. 10–11.]

163. How does carbon monoxide get into the air? If the joints of the smoke pipe leading from the furnace to the

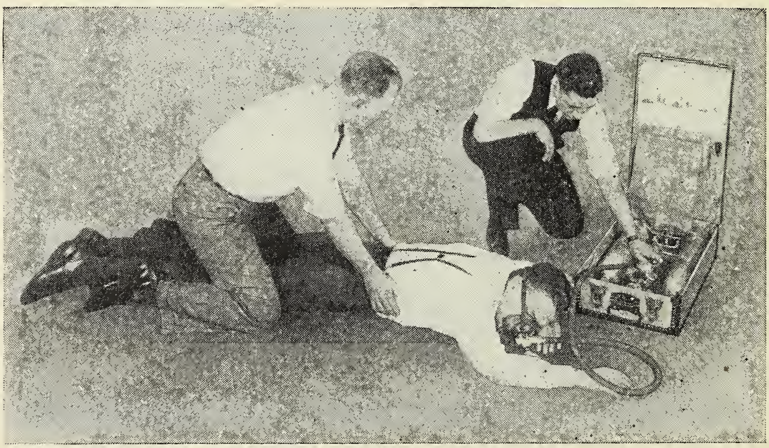
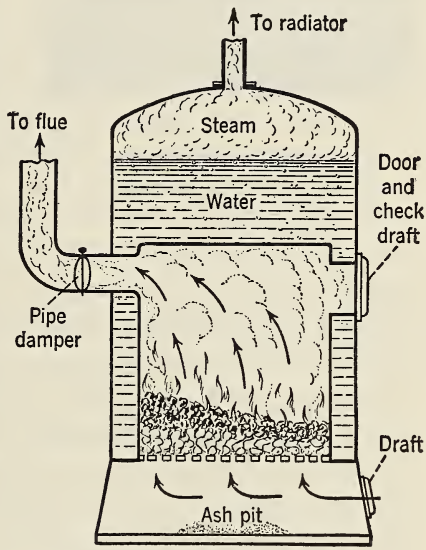


FIG. 10–11. The mask over the face of the man lying on the floor in this picture is attached to the appliance at the right which mixes carbon dioxide and oxygen. This mixture is called *carbogen* and is used with artificial respiration to restore breathing. (*Courtesy Mine Safety Appliances Co.*)

chimney are not tight, carbon monoxide may escape into the rooms of the house. A few years ago several Dartmouth students died from carbon-monoxide poisoning. The gas probably reached their sleeping rooms from poor pipe connections between the furnace and the chimney.

Some persons bank a furnace fire at night, and leave the furnace door open to check the fire during the night. [See Fig. 10–12.] Carbon monoxide may escape, especially if the

FIG. 10–12. In a steam-heating furnace of the type shown here, the air enters through the draft. If you wish to bank the fire, you close the draft and the pipe damper, so that only a small amount of oxygen enters the furnace. If you open the door or check draft, carbon monoxide may escape into the basement and gradually rise to the rooms above. If you wish to leave the check draft open when you bank a fire, leave the pipe damper at least partly open, too.



damper in the smoke pipe is closed or nearly closed. If your mother broils steak over a charcoal fire, she must be careful to have good ventilation because burning charcoal gives off carbon monoxide. White mice and canaries are quickly affected by carbon monoxide. Miners who go down into a mine that may contain carbon monoxide, may carry a cage of white mice or canaries so that they may be warned of the presence of the gas by the animals being overcome by it. [See Fig. 10–13.] However, their use has been largely

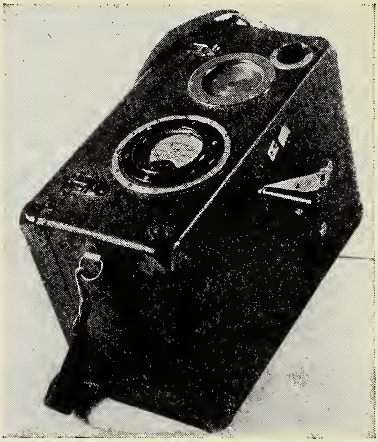


FIG. 10–13. The picture on the left shows canaries, formerly in wide use for detecting carbon monoxide in mines. The picture on the right shows the instrument which is now used more often than canaries and mice. (*Courtesy U. S. Bureau of Mines*)

supplemented by more modern and scientific methods such as the iodine-pentoxide carbon-monoxide detector, and the carbon-monoxide indicator for extremely low percentages.

Perhaps you have read a newspaper account of someone who has been overcome while running his automobile engine in a closed garage. Since an automobile engine gives off carbon monoxide, a person should never work in a closed garage with an engine running. If he starts to work in the garage, he should make sure that the door cannot blow shut.

Sometimes when a car is being driven, carbon monoxide from a leaky muffler may find its way through the floor. If such a car is closed, the persons in it may be overcome by the gas. For safety, there should be plenty of ventilation in a car.

QUESTIONS

1. Why should oily rags be kept in metal containers?
2. Why does blowing a fire make it burn more vigorously?
3. Why does blowing a candle extinguish the flame?
4. How does rapid oxidation differ from slow oxidation?
5. How should you bank a fire at night?
6. What conditions may result in spontaneous combustion?
7. The paper in the book you are reading is combustible. It is also surrounded by air. Why does it not start to burn?
8. What is meant by the *kindling temperature* of a substance?
9. What conditions are needed in order to have combustion?
10. Make a list of several substances that have a low kindling temperature. Which has the lowest?

SOME THINGS FOR YOU TO DO

1. Construct some fire sticks. See how much patience and skill you have by using these sticks to start a fire. Consult the *Boy Scout Handbook* to find out the correct procedure.

2. Ask your instructor to pour a little carbon disulfide into one small beaker, an equal amount of ether into another, and an equal amount of gasoline into a third beaker. Then he may warm a glass rod in the flame of a burner and try to ignite the vapor of each one in turn. *Pupils should not attempt this experiment themselves. It is not dangerous for a skilled experimenter, if he uses small amounts of each liquid.*

3. Take a piece of copper wire about 18 inches long. It should have a gauge number of from 18 to 22. Coil one end of the wire around a lead pencil to make a spiral about one inch long. Lower the spiral over the flame of a burning candle. Why is the flame extinguished? Heat the coil red hot and try again to extinguish the candle flame with the hot coil. Does it extinguish the flame?

THINK ABOUT THESE!

1. If you go for a long hike and build a campfire, what must you do to the fire before you go home?
2. Why is it particularly dangerous to clean a silk dress with gasoline?
3. Why should you never use a fuse of too great a capacity in a socket? How can you tell what the right capacity is?
4. Will water always extinguish fire?

WORDS FOR THIS CHAPTER

Ore. A natural mineral from which a useful element or metal may be profitably extracted.

Kiln (kĭl). An oven much used in industrial operations, to harden, burn, or dry some material, as brick.

Agent. A power, force, or means by which something is accomplished; it often refers to a person or thing acting for another person or thing.

Flammable. Referring to things that burn readily. It has the same meaning as *inflammable.*

Fuse. A special wire used in an electric circuit. It melts when there is a short circuit or an overloading of the wire by too many electrical appliances being used at once.

Flue. A chimney, or a metal or earthenware pipe, used for carrying away hot gases and smoke.

CHAPTER 11 ——— UNIT 5

How May We Control Fire?

164. How is fire a good servant? Without the use of fire, civilized man could not live in cold climates and be comfortable. On cool evenings, a blazing fire in the grate gives us warmth and makes us cheerful. The fireplace is the central point in many living rooms when the family gathers around the open fire, watching the dancing flames at play and listening to the snap and crackle of the burning logs.

When we use the phrase *refined by fire* we refer to the fact that man uses fire not only to extract such metals as iron, copper, tin, lead, and zinc from their *ores*, but also to purify various metals. Steel, too, which is composed largely of iron, is heat-treated to give it the properties which make it most useful.

Man uses fire also in making cement, which is used so extensively in constructing buildings, dams, and canal locks,

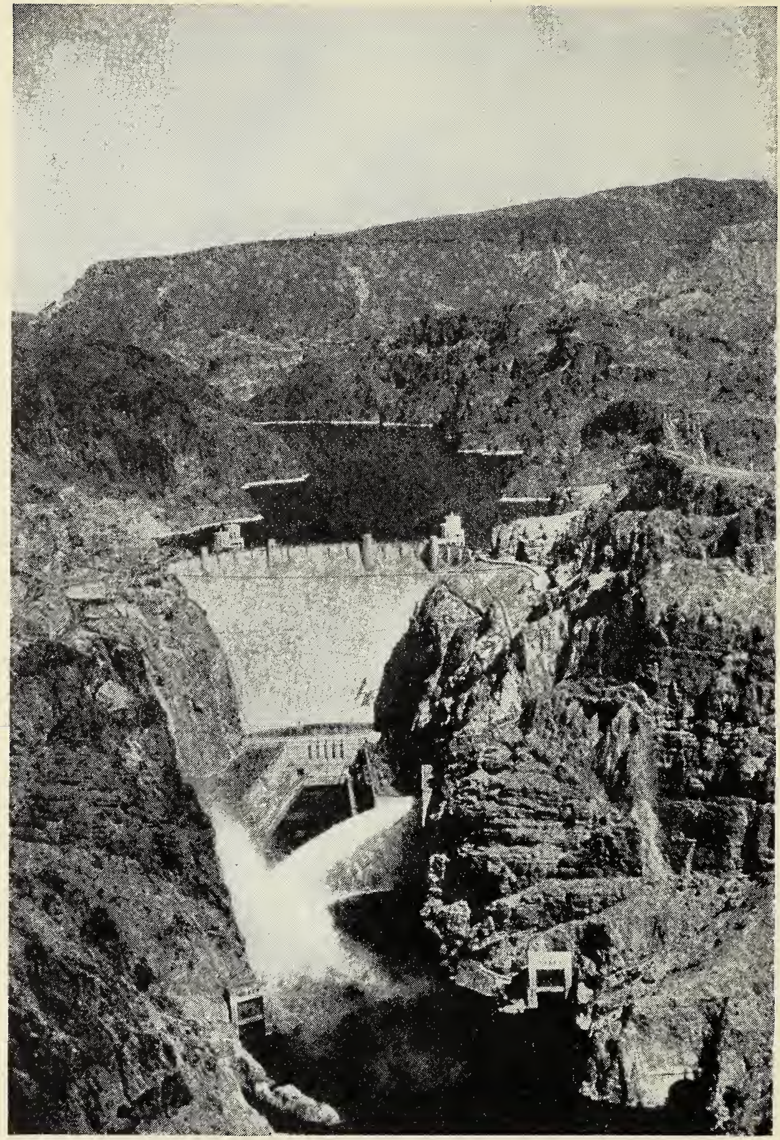


Fig. 11–1. Boulder Dam is 726 feet high and 1200 feet long. It is the highest dam in the world, but Grand Coulee Dam is larger. Boulder Dam raises the level of the water so that it can be used for irrigation and for electric power. The dam can supply nearly 2,000,000 horsepower. (*Courtesy United Air Lines*)

FIG. 11–2. This pottery is almost ready for the kiln.

and in the making of roads. [See Fig. 11–1.] The heat from gas or oil fires is used to melt the mixture of sand, soda ash, and limestone used in the manufacture of glass. Limestone is heated in huge *kilns* in order to make quicklime, which is used in mortar and plaster. In the pottery industry, fire is used in baking the clay from which brick, tile, and chinaware are made and in producing the smooth glazing on the outside. [See Fig. 11–2.]

The fireman on a small locomotive keeps shoveling coal by the hour into the firebox in order to keep up the fires that are needed to produce steam. On the large locomotive an automatic stoker is used to deliver coal to the firebox. No matter whether the coal is delivered by hand shovel or by a mechanical device, fire is the *agent* used to heat the water and form the steam which expands and drives the engine. [See Fig. 11–3.]

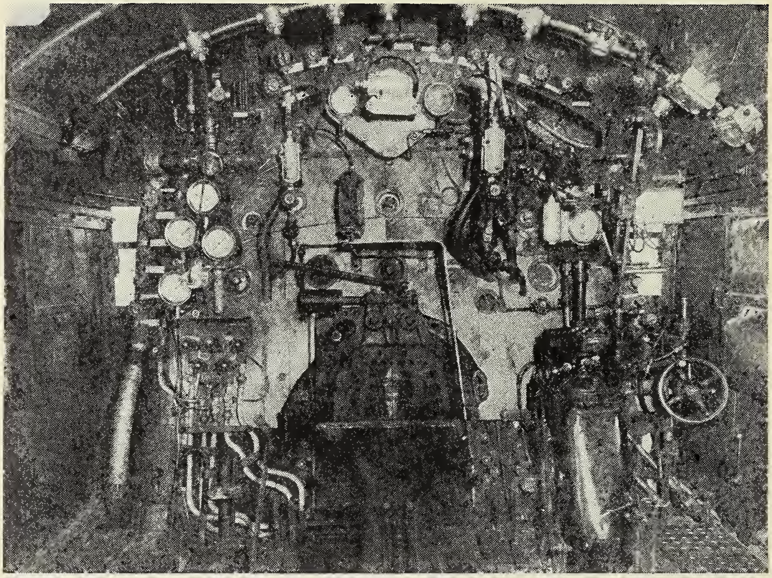


FIG. 11–3. In this locomotive cab you can see the automatic stoker, on the floor, below the center of the picture. (*Courtesy New York Central System*)

In the engine of an automobile, an electric spark is also used to set fire to a mixture of gasoline vapor and air in the cylinders of the engine. Such a mixture burns so rapidly that it causes an explosion. As these explosions occur in the different cylinders of the engine several hundred times per minute, they furnish the energy needed to drive the car. Can you name a dozen additional uses which man makes of fire?

165. Why is fire a bad master? Fire under control is so useful that one wonders how we could get along without it, but fire that gets beyond our control is most destructive. It may rage through our cities, destroying block after block of costly buildings. It may lay waste acre after acre of beautiful forest, or it may leave our homes a crumbling mass of ash and rubbish. We may know how to put out an ordinary fire,

but it is quite impossible, for example, to shut off the air supply from an entire city block or a forest which is burning vigorously. It is equally difficult to cool so much burning material below its kindling temperature.

It is true that men have built special apparatus for fighting uncontrolled fires, and firemen do win many battles, especially if they can arrive before the fire gets too great a start. Too often, however, the fire rages on, and the battle is won only after the loss has been terrific. [See Fig. 11–4.]

FIG. 11–4. Forest fires may burn only the tops of some trees, as flames leap from one tree to the next. Other fires burn only the underbrush and leaves on the ground. But such fires as the one in this pine forest burn furiously, destroying almost every tree. (*Acme*)

166. How much does destruction by fire cost us? It is found that about 10,000 persons lose their lives every year in the United States alone as a result of fatal fires. We cannot estimate the value of a human life in dollars, but the loss of about 30 lives daily from fire is so appalling that it should make us pause to inquire what part carelessness plays in so much suffering and sacrifice.

According to figures compiled by the National Board of Fire Underwriters for Insurance Companies, the loss from

insurable fires in the United States amounts to from $300,000,000 to $500,000,000 every year. For the past five years, New York City has had an average of about 75 fires daily.

The United States has an area of more than 3,000,000 square miles. When the colonists first came to America, dense forests covered nearly half the entire area of this country. Now about 40 per cent of our forests have disappeared. [See Fig. 11–5.] Apparently without thinking at all, or with

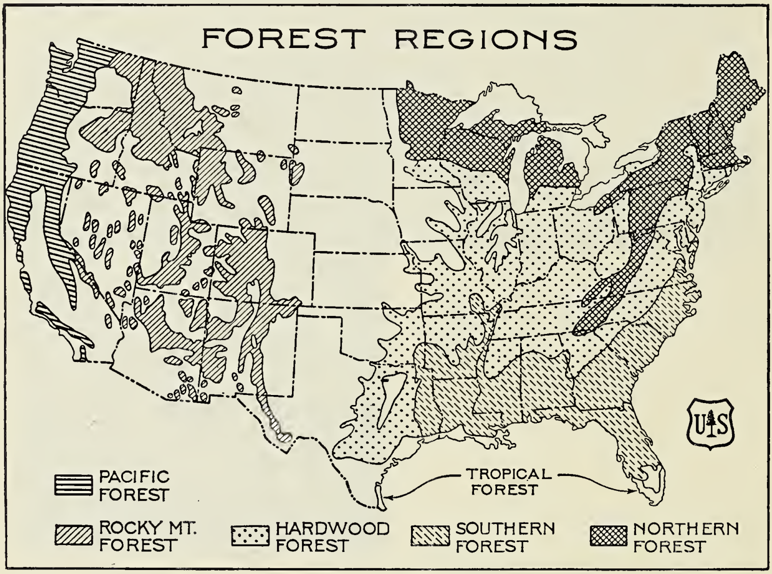


Fig. 11–5. How can we conserve the forests in the United States? What will we do when our supply of wood is exhausted? (*Photo by U. S. Forest Service*)

the thought that our forest supplies were so vast that they would prove inexhaustible, the early colonists were most destructive. They cut huge logs, rolled them together, and burned them in order to clear spaces for farming. Fires that were not set intentionally have also been responsible for the destruction of much valuable timber. It is estimated that the

annual loss from forest fires may amount to $500,000,000. If the cost were divided among all the people in the country, your share of that sum would be about $4.00. If you live the average life of seventy years, do you think you can afford to pay about $300 for your share of the losses from forest fires? It seems like a particularly heavy price to pay when you consider that at least three out of four destructive fires are due to carelessness and could have been prevented. Many persons lose their lives and their homes in forest fires, and millions of animals perish in such fires.

The constant loss from burning buildings, in country, town, and city is tremendous. Insurance does not completely cover such losses. We pay for insurance, and the greater the danger from fire, the greater the cost of fire insurance. Fire-insurance companies are businesses; they are not organized for charity. Some material destroyed by fire can never be replaced. Does not our hope of meeting such losses lie, then, in learning something about the most common fire hazards, and in finding ways to remedy them?

167. What are the causes of forest fires? A list of the most common causes of forest fires would include these:

a) *The careless camper.* Boy Scouts are taught to extinguish fires before breaking camp. The tourist who stops for the night, possibly at the edge of a fine forest, generally builds a fire to do some cooking, or to warm himself. The *careless* camper sees a few glowing embers in the morning, but he does not take the trouble to carry water and extinguish them. Later the wind may come up, fan the dying embers to a blaze and carry them into some dry leaves or underbrush. Often, too, the fire may burn for days deep in the forest floor and then burst out into a blaze. In such a manner, a forest fire may start and gain much headway before it is discovered. [See Fig. 11–6.]

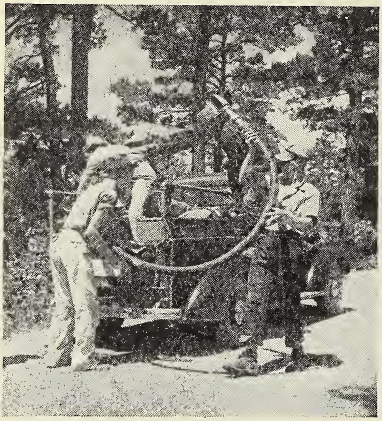


FIG. 11–6. The picture on the left shows forest-fire fighters taking a hose from a fire truck. The picture on the right shows a man using such a hose to control a fire. Where do you suppose they get the water to use in fighting forest fires? (*Photos by U. S. Forest Service*)

b) *Leaving fires unguarded.* Possibly someone starts a fire to burn some leaves, rubbish, or underbrush. He watches it for a time, but leaves it unguarded when it begins to die down. If the wind whips it into greater activity again a little later, it may then begin to spread through the leaves and dried grass into an adjacent forest.

c) *The careless smoker.* No doubt you have seen a careless smoker light a cigarette or a cigar, smoke it, and then toss the butt away. Such a butt may easily burn for several minutes, unless care is taken to extinguish it. Such a fire hazard may be thrown from a passing car into dry grass along the roadside, or it may be dropped by a tourist, a hunter, or a camper into some dried leaves of the forest itself. In a few minutes a fire may be spreading with dangerous rapidity. The careless smoker may start a fire, too, by throwing away the match he used to light his cigarette, without taking the trouble to see that it is extinguished. Careful smokers al-

ways extinguish the fire in remnants of cigars, cigarettes, or burning pipe tobacco before throwing them away.

d) Other causes. A flash of lightning may set fire to a tree which it strikes. Forest fires have been started in this way. A locomotive, passing along a track that runs through a forest, may throw out hot cinders from its stack. Often such cinders are hot enough to set fire to leaves and underbrush. Formerly, many forest fires were started in this way. A screen is now placed over the top of the smokestack of the locomotive to prevent the escape of hot cinders.

168. What is the remedy for forest fires? A skillful doctor studies the nature of a disease, learns how it is caused, and then suggests a remedy. The most important remedy one can suggest to prevent forest fires is to educate *all persons to be careful at all times.* That means that fires are not

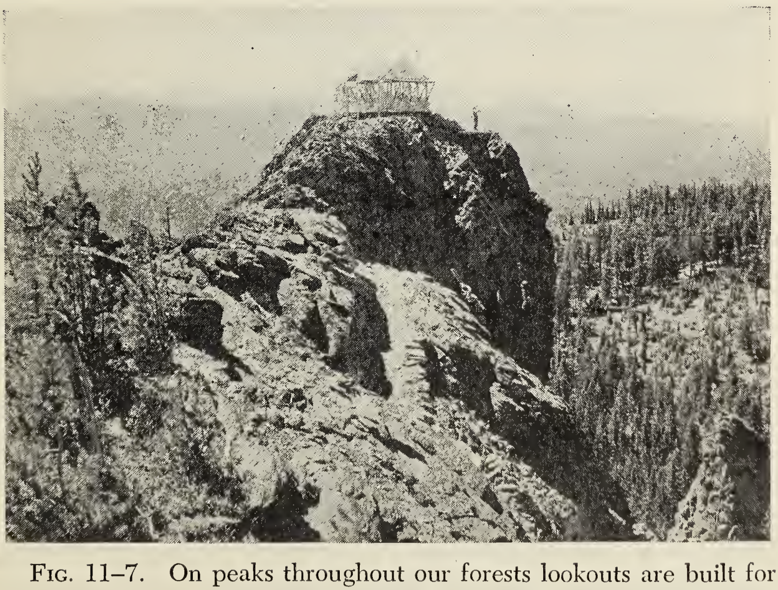


FIG. 11–7. On peaks throughout our forests lookouts are built for forest rangers. From these lookouts, the rangers can see the forested areas for miles on all sides. (*Photo by U. S. Forest Service*)

to be left unguarded. It means that every person who starts an outdoor fire *must be responsible to see that it is extinguished.* It means that smokers must be taught the folly of throwing away burning matches or cigarette butts without extinguishing them. It means that persons must not burn rubbish or dead leaves out of doors during dry seasons or when the wind is blowing strongly.

Forest rangers do much to prevent the spread of disastrous forest fires. They patrol the forests. They have lookouts at high points from which they keep watch so that any fire is quickly located. [See Fig. 11–7.] Aviators, too, fly over forest areas to locate small fires which might spread and become dangerous. The newest procedure is to drop the fire fighters by parachute from the plane. They are equipped with chemicals for fighting fires. This peacetime blitzkrieg has proved its worth in checking many fires which otherwise might have spread beyond control before fire fighters could reach them.

169. What are some common fire hazards around the home? A complete list of the causes of fires in and around the home would be rather long, but we may mention a few of them. [See Fig. 11–8.]

a) *Hot ashes.* If ashes are taken from a stove or furnace and placed in a wooden box, they may set fire to the box. Fires have resulted from this cause. *Ashes should always be kept in metal cans and never in wooden containers.*

b) *The thoughtless smoker.* A short time ago one of the authors of this book saw a burning cigarette scorching the counter in a tailor's shop. He counted ten scorched spots on that counter. The unextinguished cigar or cigarette butt left lying on a piece of furniture, or dropped carelessly on the rug, is the cause of many fires in the home. Hot coals or ashes flicked from a cigar or cigarette may burn a hole in

FIG. 11–8. Every day homes are lost by fire. Usually such fires are caused by someone's carelessness, and they could be avoided. Look around your own home today to be sure you have no fire hazards. (*Photo by John Warren Wright*)

one's clothing, in a fine rug, or in an automobile cushion. A fire may result too. Bed covers have been set on fire by a smoker who fell asleep while smoking in bed. In such an event, the smoker is almost certain to burn to death.

c) *The kitchen gas range.* A woman reaches across a lighted gas burner to get a pan from a rear burner. Her sleeve catches fire. She gets a nasty burn and may set fire to some *flammable* material in the kitchen, too. Curtains and draperies are sometimes hung so close to the gas range that they may catch fire when a breeze blows them a little to one side.

An inexperienced person may open the oven door, light the oven burner, and then close the door so suddenly that the draft extinguishes the fire. Then the oven fills up with a

mixture of gas and air which is dangerously explosive. If one tries to relight such an oven before it has been aired out, a violent and dangerous explosion may occur.

The gas has been turned on and lighted. Grease has been put in the frying pan over the fire when the telephone rings. When the cook returns, the grease is all ablaze. [See Fig. 11–9.] Some persons, without thinking, pour the flaming

FIG. 11–9. This is not the way to extinguish burning grease. The woman could be severely burned by the flames, which are only scattered by the force of the water. (*Courtesy American Mutual Liability Insurance Co.*)

grease into the sink or pour water into the frying pan. In either case the hot grease will spatter and will be likely to burn the person badly. It may also set fire to any flammable material that is near the sink. Even if the water is turned on in the sink, the flaming grease floats on the surface of the water and continues to burn. The correct thing to do is first to turn off the gas, and then to cover the frying pan with a metal lid. A couple of tablespoonfuls of baking soda thrown into the frying pan will extinguish the flame. *Baking soda is a good dry extinguisher for fire.*

d) *Dangers from dry cleaning.* In some homes, gasoline is still used for dry cleaning, or for removing grease spots. It is dangerous, for several reasons. Unless there is a good

draft of air, the person doing the work may be suffocated by the gasoline vapor. In the second place, its vapor mixes with the air in the room and forms an explosive mixture. It has a low kindling temperature, and it is easily ignited. Silk, in particular, may produce an electric spark when it is rubbed. If the electric spark ignites the gasoline vapor, the person who is doing the work is sure to be burned, sometimes fatally.

Carbon *tetrachloride* (tĕt′rȧ·klō′rīd) is a liquid which does not burn. It is just as satisfactory for removing grease spots or for dry cleaning, as is gasoline. It is used for filling Pyrene fire extinguishers because it is suitable for extinguishing fires. A rather large can of carbon tetrachloride kept in the home may be used for removing spots made from oil, grease, lipstick, or chewing gum, and it can be used as a fire extinguisher in case of an emergency. It must be used where there is good circulation of air, for *its vapor is suffocating.*

e) *Fires caused by electricity — the electric iron.* The maid or housewife may be doing the ironing when the telephone or doorbell rings. In her haste to answer, she thoughtlessly lets the iron stand on the ironing board, with the current on. If the conversation is a long one, the board may be on fire when she returns. Before any bell is answered or other interruption permitted, the switch should be turned off, and the iron placed on a metal holder.

Defective wiring. Some persons with too little knowledge of electricity try to do their own wiring. The resulting work is faulty or defective. To avoid danger from fires, all wiring should be done by skilled electricians. After a new house has been wired, it must be inspected by a Board of Fire Underwriters before the current from the street is turned on, or before any fire insurance can be issued.

Short circuit. Floor lamps are used in a great many homes. After some use, the insulation covering the wires from such

lamps may wear away, leaving the wires bare. If the two wires touch or cross each other, they will produce a short circuit which may result in a fire. Short circuits may come also from loose connections at the plug or in sockets. Wires, sockets, and plugs should be inspected from time to time and repaired before there is real danger of their causing short circuits. A short circuit always causes an overload and " blows " a *fuse,* if the fuses have been properly installed. It is possible to get an overload, too, by plugging in too many electrical appliances on one circuit. [See Fig. 11–10.]

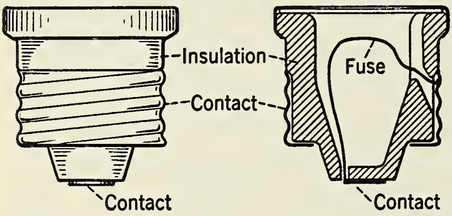
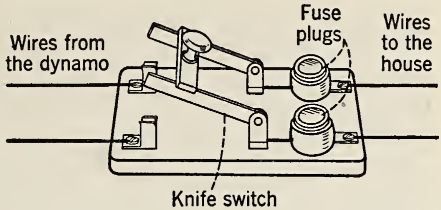


Fig. 11–10. Plug-type fuses. The fusible metal is surrounded by non-flammable material.

Oversized fuses. If a short circuit or an overload occurs, the fuses should " blow." When a fuse " blows," or burns out, it should be replaced with a fuse of the same size, or capacity, but never with one that will carry more current. The capacity of the fuses to be used should not be determined by the kind of machine that a person wishes to operate by electricity. It depends upon the amount of current which the wires may carry safely. The amount of current that a fuse will carry is plainly stamped upon the *contact,* a small piece of brass at the end of the fuse plug, which makes the connection. To avoid fires, one should never put a coin in a socket to take the place of a fuse; nor should one use oversized fuses. Fuses are installed in metal boxes. *If your house should catch fire, you should cut off the electric current by pulling the switch.* [See Fig. 11–11.]

Fig. 11–11. Fuses and a knife switch are used for protection.



Electric bulbs. A lighted electric bulb on an extension cord may come into contact with draperies, bed clothing, or other flammable material. A boy in a boarding school set fire to his mattress by placing a lighted bulb upon it when he went to supper. A nurse at one time placed a lighted electric bulb between the sheets to keep a sick girl's feet warm. The heat from the bulb ignited the sheets, and the unfortunate girl was burned to death.

f) Fires caused by heaters. There are several fire hazards in connection with the heating of a home. The *flue* or chimney should be examined at least once a year to see that it is not *defective.* If it becomes partially filled with soot, a hot fire may kindle the soot. Then the chimney becomes overheated near the roof, or glowing cinders may fly from the chimney and lodge on the roof. Wood-shingle roofs sometimes catch fire from this cause. A chimney needs to be cleaned once a year to prevent chimney fires, if the fuel used forms much soot.

Fires may occur if the joints of the smoke pipe become loose and separate. They need to be checked occasionally and tightened if they are too loose. Then too, the smoke pipe must not be placed too near to wooden partitions or wooden beams.

Some persons are so careless that they still use kerosene in order to kindle a fire. Persons have been badly burned as a result of throwing kerosene on live coals or on a flame.

Portable heaters, especially kerosene burners, are fire hazards. There is danger from spilled kerosene during the filling of the stove. Furthermore, the stoves are easily tipped over. In this way the oil may be spilled out and thus catch fire.

One should never go to bed and leave a fire burning in a fireplace, especially if it is not guarded by a fire screen. Wood nearly always contains some water. As the wood burns, steam is formed, and the expanding steam may throw live coals or sparks out upon the rug or the floor.

g) *Celebrations.* Bonfires built to celebrate athletic victories may become a fire hazard. Still more dangerous, however, are the firecrackers and the fireworks used to celebrate the Fourth of July in some localities. Both Roman candles and sky rockets are a fire menace. In the state of New Jersey, where an amateur is not permitted to handle fireworks, few fires and injuries now occur on or near July fourth. It seems just as patriotic to celebrate the Fourth of July quietly at a picnic as it does to have a so-called "Glorious Fourth" with giant firecrackers and fireworks. [See Fig. 11–12.]

A Christmas tree of cedar, spruce, or balsam is easily kindled and burns most rapidly. Sometimes, too, it is loaded with flammable decorations. The use of wax candles on such a tree is very dangerous, and even a small electric bulb in direct contact with a branch of the tree may heat it to its kindling temperature.

In decorating the house for a party, tissue paper or crepe paper is sometimes used to enclose electric bulbs. Such decorations form a fire hazard, as the bulb may get hot enough to kindle the paper.

170. What are the fire hazards of the stable and the garage? Smoking around a barn or stable is particularly dangerous. The hay and straw used for feeding and bedding

Fig. 11–12. Going on a picnic is a safer way to celebrate the Fourth of July than setting off fireworks, and it is more fun, too. But even picnics present certain dangers which we should remember. Be especially cautious of open fires, for many shrubs and trees are destroyed every year by careless campers. Your fire should be carefully and completely extinguished before you leave it. (*Philip D. Gendreau*)

cows and horses are easily kindled and burn with great rapidity. A lantern, too, must be handled with extreme care when it is used around a barn or stable. A flashlight is safer.

In most states it is illegal to store gasoline in a private garage. Gasoline should always be stored in metal tanks which are buried underground. That person, too, who lights a match to see whether there is plenty of gasoline in the tank of his car is just as foolish as the one who looks with a lighted match for a gas leak in his cellar. He is likely to find the leak, but he is likely to have a few scars to wear for the rest of his life as a souvenir of his explorations. A heater in a garage in winter may also be a fire hazard.

171. How can you prevent dangerous fires? There is an old adage that it is the burnt child that fears the fire. Anyone who has stood by while his home and his dearest possessions are burning will always be cautious about fires. But such experiences are costly and one may learn to be careful without them.

You can help to avoid fires by learning all you can about the most common fire hazards. You can probably add to the list of dangers we have just been studying. You have learned, too, some of the principles involved in extinguishing fires. You should be able to apply them successfully to small fires, but you will need help to extinguish a large fire or one that is spreading rapidly. Every boy or girl should know where to find the fire-alarm box that is nearest to his home or to his school, and know how to turn in an alarm. He should also know that it is criminal to turn in a *false* alarm; particularly because some fireman may be severely injured or killed in racing to answer such an alarm. Many telephone books tell exactly how to proceed in reporting a fire. It is not a very great burden to memorize the telephone number of the fire department.

172. **What kinds of fire extinguishers are in common use?** Water is useful for putting out some fires, but it is of little value in extinguishing oil fires. Some extinguishers are valuable for one type of fire, but not for other types. Let us mention a few examples:

a) *The Pyrene extinguisher.* From Figure 11–13 we see that the Pyrene extinguisher consists of a type of pump which can be used to squirt a liquid into a flame. Carbon tetrachloride, the liquid that is used, easily changes to a vapor. That vapor does not burn. It forms a blanket over the flame and shuts off the oxygen supply. It is useful for extinguishing fires from burning oils and fats. Some states require the owner of a motor boat to keep such an extinguisher in the

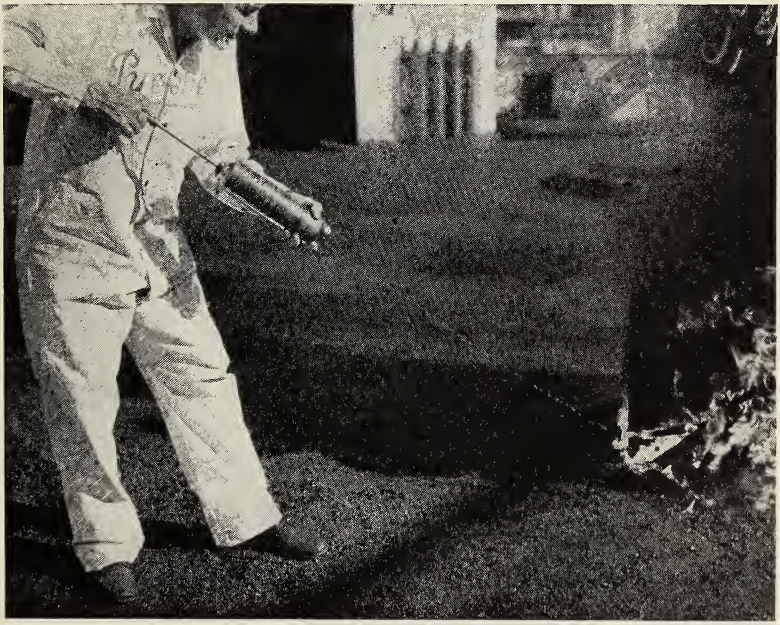


FIG. 11–13. A Pyrene extinguisher being used correctly to put out a fire. Notice that the stream is directed toward the base of the fire, rather than toward the smoke and flames. (*Courtesy Pyrene Manufacturing Co.*)

boat at all times when it is in use. Some automobile owners carry such an extinguisher to extinguish oil which may be kindled around the engine as the result of a short circuit. One does not get an electric shock, if he squirts a stream of carbon tetrachloride upon live electric wires.

b) *The soda-acid extinguisher.* The cylinder of the extinguisher shown in Figure 11–14 is filled nearly full of water in which about a pound and a half of baking soda has

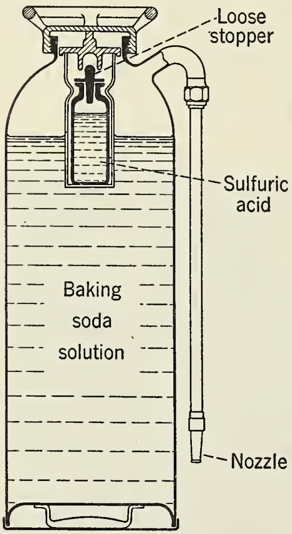


FIG. 11–14. The soda-acid extinguisher is a handy one to have around a home or farm. It is inexpensive and simple to operate. To use such an extinguisher, one turns it upside down. The sulfuric acid then spills out into the soda, and carbon dioxide is set free. Such an extinguisher should be tested at least once a year. Then it must be refilled.

been dissolved. The small bottle contains sulfuric acid. When the extinguisher is turned upside down, the acid spills out and attacks the soda. A large volume of carbon dioxide is set free by the action of the acid on the soda. It expands and forces a stream of water and carbon dioxide gas upon the flame. Such an extinguisher is useful for putting out burning wood, leaves, or rubbish. It is of no value for putting out an oil fire and it must not be used to put out a fire caused by electricity.

Fig. 11–15. The beaker shown here has in it foam created by 100 cubic centimeters of baking-soda solution which were added to 100 cubic centimeters of a solution of aluminum sulfate. Extract of licorice has been added to make the foam tougher. (*Photo by Wettlin*)

c) *Foam extinguishers.* In extinguishers of the type just described in the preceding paragraph, the carbon dioxide escapes rapidly. To prevent such rapid escape of this gas, some substance is added to the liquid in the extinguisher to keep the gas from escaping and to form a blanket of foam.

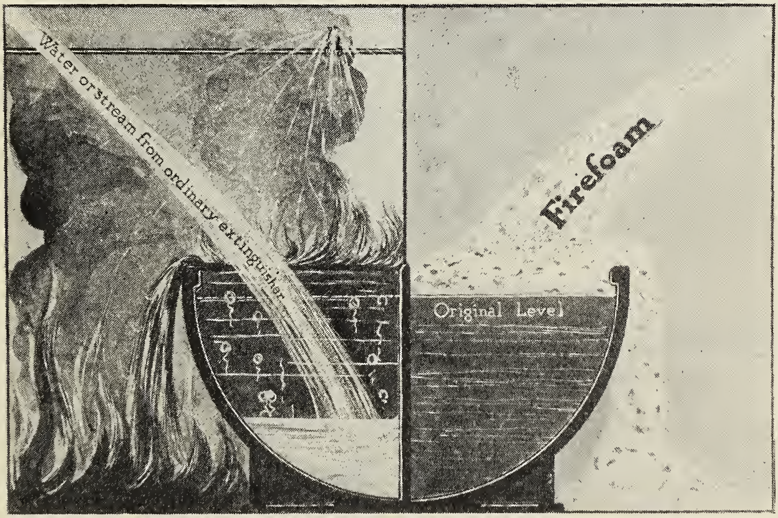


Fig. 11–16. The picture at the left shows water being used in an attempt to put out an oil fire. It sinks to the bottom, and the oil overflows, still burning. The picture at the right shows a foam extinguisher in use. (*Courtesy American-LaFrance-Foamite Corp.*)

The beaker of Figure 11–15 consists of baking soda dissolved in water. A small quantity of extract of licorice is added to the solution to make a tough film which entangles the carbon-dioxide gas and forms a thick, stiff foam. The beaker contains a solution of aluminum sulfate which acts upon the baking soda and sets free the carbon-dioxide gas. If the foam formed by such chemicals is applied to a vat, or tub, of burning oil, the foam spreads over the surface of the oil and smothers the fire. [See Fig. 11–16.]

d) Carbon-dioxide extinguisher. In the extinguisher shown in Figure 11–17 the cylinder is filled with water. A

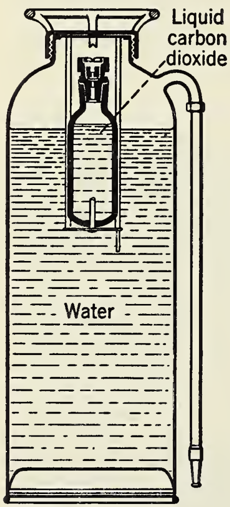


Fig. 11–17. A new type of carbon-dioxide extinguisher uses liquid carbon dioxide. The soda-acid extinguisher gets carbon dioxide from the action of the acid on the baking-soda solution. But both extinguishers depend on carbon dioxide for their effectiveness. The stopper of this extinguisher is tightly sealed. It is of soft metal so that it will be easily punctured when the extinguisher is turned upside down and tapped on a floor. Then the liquid carbon dioxide evaporates and forces the water out of the extinguisher.

small metal bottle is filled with liquid carbon dioxide, which is under rather high pressure. When the cylinder is turned upside down, and struck sharply, the metal bottle is punctured. The liquid carbon dioxide evaporates almost instantly and forces out through the nozzle a stream of water and carbon dioxide.

e) *Dry extinguishers.* Baking soda thrown into a flame sets free carbon dioxide which smothers the flame. Dry ice evaporates and forms carbon dioxide. Hence a piece of dry ice makes an excellent fire extinguisher. Sand may be used to blanket a flame. Such a chemical as sal ammoniac may be used to put out a fire.

QUESTIONS

1. Make a list of all the things about your home that you think might act as fire hazards.
2. Check all of those in the list of No. 1 which you think you can correct and tell how you would do it.
3. What are Boy Scouts taught as to the best ways to build fires and how to take care of them?
4. Why is water of little value in putting out a gasoline fire?
5. What type of extinguisher would you use for putting out burning oil?
6. What type of extinguisher would you use for a fire started by a short circuit?
7. Suppose you live in New York City. Does a forest fire in the state of Mississippi cost you anything? Explain.
8. How do you think that insurance rates would be affected if everyone could be taught to be careful about the control of fires?

SOME THINGS FOR YOU TO DO

1. Check all the electric wires leading from the floor lamps in your home to the sockets. Do you find any kinks in the wire? (Stepping on a kinked wire may cause a short circuit.) Do you find any spots from which the insulation has been worn away? Do you find any loose sockets?
2. Make a fire extinguisher. Fill a quart milk bottle a little more than half full of water in which you have dissolved almost all the baking soda that will dissolve in it. Ask your instructor

to make for you a 20-per-cent solution of aluminum sulfate in water. Fill a test tube (about 6 inches long and ¾ inch in diameter) about two-thirds full of the aluminum sulfate solution and lower the test tube into the milk bottle, as shown in Figure 11–18. Fit a rubber stopper with a tube as shown in the figure and then stopper the bottle tightly. It is better to wire the stopper so that it cannot be pushed out of the bottle. Wrap a towel around the bottle before you use it. To use it, turn the bottle upside down. Your instructor will probably help you to test the value of the extinguisher.

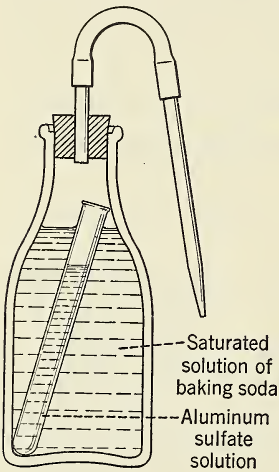


Fig. 11–18. A home-made fire extinguisher which is easy to make and easy to operate. Of course, the walls of the bottle must be very strong. Why is it a good plan to wrap a towel around the bottle before you test the extinguisher? If you make such a fire extinguisher for your home, where might be the best place for it?

3. Ask your instructor to pour 100 cubic centimeters of a saturated solution of baking soda in water into a large beaker (1000 cubic centimeters in capacity). Stir into the baking-soda solution a teaspoonful of licorice extract. In another small beaker make a 20-per-cent solution of aluminum sulfate. Pour 100 cubic centimeters of this solution into the large beaker. The instructor may set fire to a little alcohol in an iron dish and use the foam from the beaker to put out the fire.

The Earth Is Our Home

WE have explored three of Aristotle's so-called elements: water, air, and fire. In this unit we are going to get better acquainted with the fourth, which is earth.

The earth is man's home and up to the present time, man has not left the earth. But he has ventured into the upper part of the earth's atmosphere in stratosphere flights. On his flights into the stratosphere he has come closest to leaving the earth altogether.

You may have read stories about trips to the moon in rockets or balloons. But until such adventures really happen, we have plenty to explore and enjoy on the earth. Even if we cannot travel over land and sea and through the air to explore the earth, we can find books about the places we are interested in. Other persons who have seen the places will tell us about them. With a little help, we can imagine a visit to the hot springs in Iceland. On another day we can travel by imagination to New Zealand to see some of the

beautiful geysers which are found in only a few places on the earth. On the way home it will be worth our while to stop at the island of Hawaii and to visit the crater of the famous volcano, Kilauea. The next day we may visit the Grand Canyon. Looking down about a mile to the Colorado River in the canyon, we may wonder how many years it has taken this river to carve out such a channel.

In exploring the earth, we shall be interested in the changes that are taking place in its surface. We shall see certain forces building up the earth and other forces destroying it. We shall also want to explore the treasures in the earth — to see men at work taking iron and copper and tin and gold from the earth, sinking pipes to get oil and gas, and mining coal for fuel and power.

Think about these!

1. Are mountains being formed at the present time?
2. Which are older, the Rocky Mountains or the Appalachians?
3. How is a coffee percolator like a geyser?

Words for this chapter

Glacier (glā′shẽr). A field or body of ice, formed in a region where snow falls in greater quantities than it melts.

Reflected. Turned back, as when a sound is echoed.

Thrust (noun). A push, such as is exerted by some force below the surface of the earth.

Lava (lä′vȧ). Liquid melted rock, usually from a volcano.

Fissure (fĭsh′ûr). A crack or crevice in the earth's crust.

Pumice (pŭm′ĭs). A light, spongy rock formed from lava.

Diffused (dĭ·fūzd′). Scattered like rays of light by dust particles.

Quiescent (kwī·ĕs′ĕnt). Quiet or nonexplosive.

Igneous (ĭg′nē·ŭs). Resulting from the action of intense heat.

CHAPTER 12 ______________ UNIT 6

How Is the Earth's Surface Built Up?

173. How irregular is the earth's surface? If you look along a level street more than a half mile long, and then imagine that the street is standing on end, you may have an idea of the height of El Capitan (ĕl kä′pē·tän′) in Yosemite (yō·sĕm′ĭ·tē) National Park. As you see its walls extending almost vertically for about 3000 feet, you may think the surface of the earth is irregular. [See Fig. 12–1.] Or suppose you are standing at the north rim of the Grand Canyon of the Colorado River in Arizona and looking across the Canyon, a distance of at least ten miles. As you look down into the canyon's depths, you will see the river, a mile below the rim of the Canyon. This river is still cutting the river bed to greater depths. As you look at it, you will think that the earth's surface here is deeply cut and grooved. [See Fig. 12–2.]

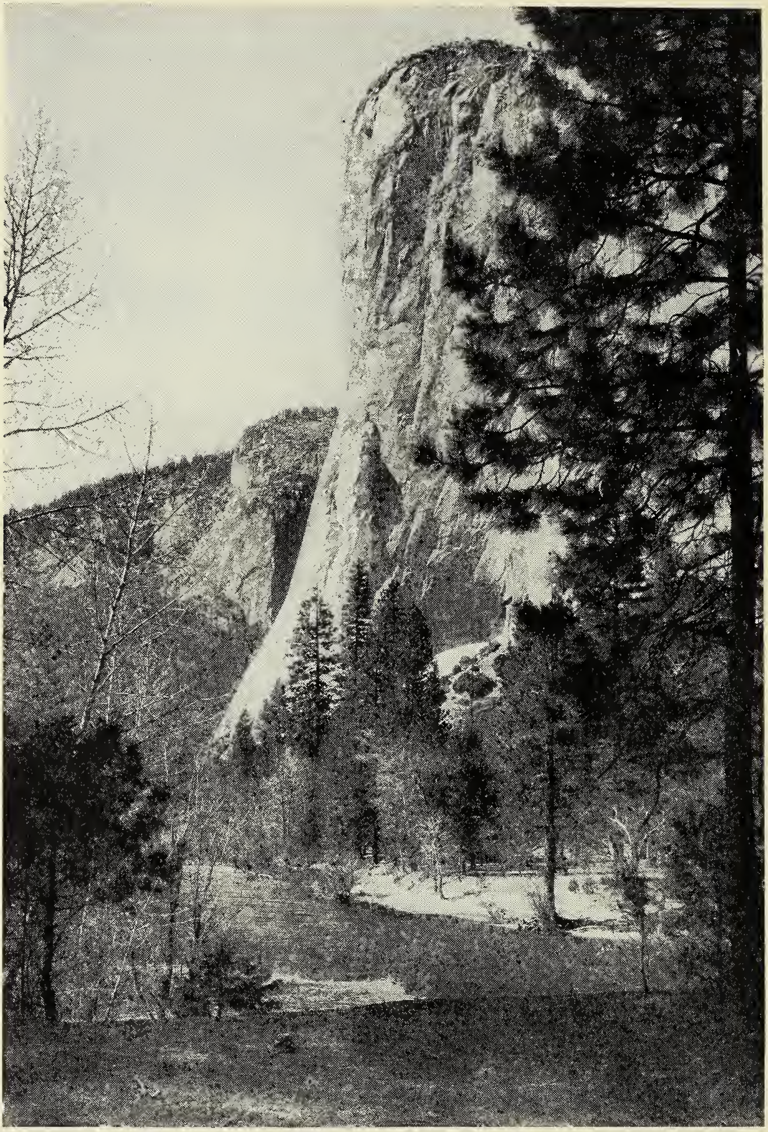


Fig. 12–1. The huge rocky mass rising from the bottom of the canyon in Yosemite National Park is called El Capitan, which in Spanish means *The Captain.* (*Southern Pacific Photo*)

Fig. 12–2. Does it seem possible that running water could have cut and carved such a canyon? It took many thousands of years. (*Union Pacific Railroad Photo*)

But suppose that you are standing on the main highway between Dallas, Texas, and the state capitol at Austin. You can see for miles and miles in any direction you turn. From such a point of view, you might believe that the earth is very flat and smooth. One gets the same idea of flatness as he travels through southern Florida over the famous Tamiami (tă′mī·ăm′ĭ) Trail. You have probably heard the story told of the different blind men who were trying to find out the shape of an elephant. By the sense of touch one of them found him like a wall, another found him like a pillar, a third found him like a fan, and a fourth found him like a rope. What part of the elephant did each one examine? In a similar manner we change our ideas of the smoothness or the irregularity of the surface of the earth as we move from place to place.

We must try to think of the surface irregularities in relation to the size of the earth *as a whole.* If it could be reduced in size to that of a large orange, its surface would probably be smoother than that of the skin of the orange.

174. How do the surface features of the continents look? You have seen the rocks in some quarries. They may be in level layers, or they may be folded and twisted into various shapes. [See Fig. 12–3.] Does it not seem that extremely great forces must have been at work, throughout millions of years, lifting the continents well above sea level and folding the rocks of the earth's crust to form high mountains and deep valleys? There is enough water in the oceans to have covered the entire surface of the earth to a depth of hundreds of

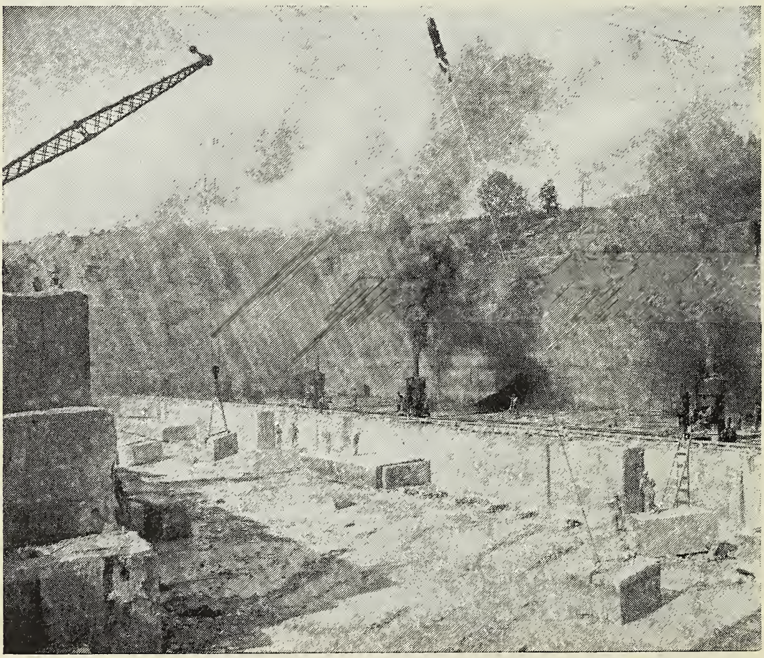


FIG. 12–3. Sometimes layers of rock are folded and twisted. When the layers are level, as they are here, the rock is easier to quarry. (*Courtesy Indiana Limestone Co.*)

feet, if the parts underneath the oceans had not *sunk to great depths* at the same time that the continents were being pushed upward.

Let us look at a relief map of the continents. Notice that the *greatest uplifting* of rock masses to form high mountains has often occurred near the *deepest oceans*. In North America, for example, we find the Sierra Nevadas and the Cascade Range not far from the Pacific Ocean, the largest and deepest ocean. The Appalachian Mountains in eastern North America were at one time much higher than they are at present. They are older mountains than the Sierras or the Rocky Mountains and they have been worn down to a greater extent. The Great Plains and prairies lie in the interior between the mountains, which are nearer the coasts.

In South America the lofty Andes Mountains extend the whole length of the continent along the Pacific Ocean. The highlands of the eastern part of the continent form the plateaus of Brazil and Guiana (gē·ä′nȧ). The plains lie in the central portion.

Changes in elevation are still taking place. Some coastal plains are slowly rising. At other places the land is slowly sinking. In some places the ruins of ancient cities are found below the ocean. Men who have explored the bottom of New York Bay have found evidences that the Hudson River at one time extended a considerable distance out into what is now the ocean. Geologists speak of this part of the Hudson Valley as a *drowned* river valley. The gradual sinking of the land tends to decrease the land area, but a rising coast line increases the area, or size, of a continent. In many cases the change in elevation is so slow that it amounts to only a few inches in a year.

175. What are the greatest heights? In the eastern part of the United States the highest peak is Mount Mitchell in

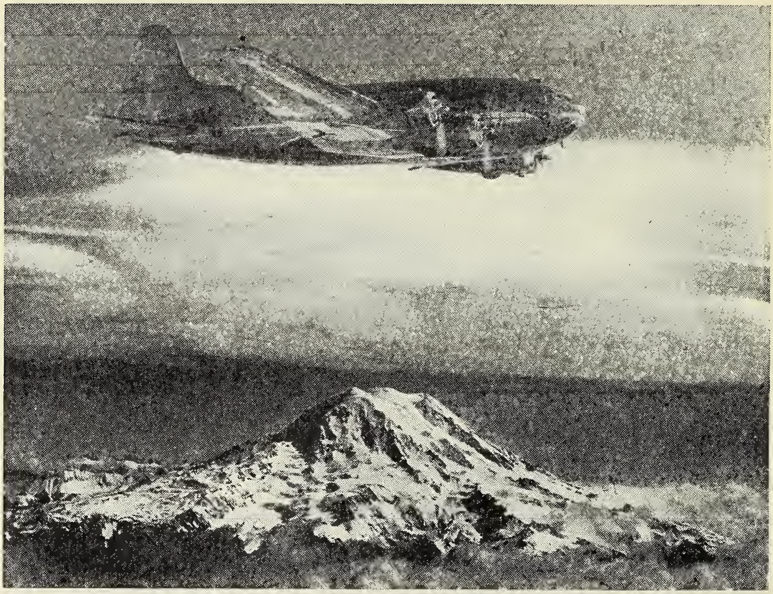


FIG. 12–4. The view of Mount Rainier from the air is breath-taking. The glaciers on its top make the mountain a difficult one to climb. (*Courtesy Pan American Airways*)

North Carolina. This mountain is somewhat less than 7000 feet above sea level. In the state of Washington, in the northwest, Mount Rainier (rā·nḗr′), which is also called Mount Tacoma (tȧ·kō′mȧ), rises to more than twice that height. [See Fig. 12–4.] Its top is covered with a group of fourteen *glaciers*. The mountain is easily visible from Seattle, a hundred miles distant.

We find, too, that in Colorado and in California there are several mountain peaks that are more than twice the height of Mount Mitchell. Pikes Peak, in Colorado, is more than 14,000 feet above sea level. It does not seem so high, however, if one is viewing it from Denver, because that city is situated on a plateau one mile above sea level. Mount McKinley, in Alaska, is the highest known peak in North America.

It is more than three times as high as any peak in the Appalachian mountains. [See Fig. 12–5.]

In South America, Mount Aconcagua (ä'kôn·kä'gwä) lifts its snow-crowned head to a height of more than 23,000 feet above the level of the sea. A visitor on snow-capped Mount Blanc of Switzerland can look down upon Lake Geneva from a height of nearly 18,000 feet. It is the highest mountain in Europe, although some other peaks in Switzerland are nearly as high. The highest known peak in the world is in the Himalaya (hĭ·mä'l*ȧ*·y*ȧ*) mountains, where Mount Everest towers to a height of more than 29,000 feet above sea level. No man has yet reached the summit of this lofty mountain, despite the fact that many attempts have been made to scale it.

Fig. 12–5. A part of the Canadian Rockies known as Ten Peaks. These ten mountains rise above beautiful Lake Louise, partially surrounding it. They are some of the highest peaks on the North American continent. (*Courtesy Canadian Pacific Railway*)

176. How deep is the ocean? At one time the depths of the ocean were measured by means of a *sounding line.* A weight was lowered on a steel wire, and then the length of wire was measured. Now a much simpler and quicker method is used. Ocean depths are measured by sounds. A sound is produced at the bottom of a ship. The sound wave travels through the water to the bottom of the ocean and is *reflected* back to the ship, just as an echo sometimes comes back to you from a forest or a cliff if you stand some distance away and shout toward it. Men have learned how fast sound travels in water. By keeping an accurate measurement of the time it takes the sound to travel from the bottom of the ship to the bottom of the ocean and back, men can easily calculate the depth. The instrument used in making such measurements is called a *fathometer* (fă·t͟hŏm′ē·tẽr). Sound travels about 4700 feet a second in water. If a listener counted 12 seconds from the time a sound wave started downward until it returned, he would know that it took 6 seconds to reach the bottom. He would then multiply 6 by 4700. The answer would be 28,200 feet, which would be the depth of the ocean at that place.

The ocean depths have been measured at many places, both near the shore and far from it. Near Puerto Rico, places have been sounded in the Atlantic Ocean which are more than five miles in depth. Of course not all of the depths of the vast oceans have been explored, but several places in the Pacific Ocean have been found which are at least six miles in depth.

177. How would the earth look if we could see it as a whole? The distance from the greatest ocean depth to the top of the highest mountain is probably about twelve miles. If we were to build a model of the earth and make it 100 feet in diameter, the extreme variations in the surface of the

model, if made to represent the highest mountain and the greatest depth, would be less than two inches on the model. If we reduced the diameter of the model to 10 inches, the irregularities would be much less than a quarter of an inch. From a relative point of view, then, the earth is fairly smooth. It only seems rough and uneven because we cannot see it as a whole.

178. **How are mountains built?** Some geologists believe that at one time the earth as a whole was much hotter than it is now, and that its surface shape could be more easily molded. At one time geologists believed that the center of the earth was liquid, with a crust at the surface. They are now fairly sure that the earth is solid most, if not all, of the way through; but we often speak of the earth's *crust* when we mean the part near or at the surface.

The portions of the earth that are now beneath the oceans seem to be composed of denser materials than the present land areas. As the denser portions of the earth's crust gradually subsided, or settled, the less dense portions were pushed upward to form the continents. Then the depressions, or lower places, gradually became filled with water, and the additional weight of the water helped to make the upward push upon the land areas even greater than it was before.

Men have constructed models of clay to show on a small scale the effects of sidewise *thrusts,* similar to those which the oceans produce. Let us construct a trough a couple of feet in length, two or three inches wide, and about two inches deep. We then fill the trough with several layers of different-colored clay, which is *plastic,* or capable of being molded. We cut a board to fit one end of the trough and fasten a stick to it as a handle. If we push sidewise against the clay at one end of the trough, while the other end is held firmly against a vertical surface, we shall find that layers of clay are pushed

upward to make a miniature mountain range near the end at which the sidewise thrust was applied. The walls and bottom of the trough prevent the clay from spreading out in any direction except upward. [See Fig. 12–6.]

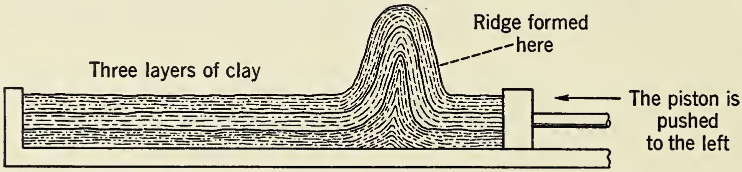


FIG. 12–6.

Let us repeat the experiment and produce a sidewise push at each end. We find that two miniature mountain ranges are produced, one near each end. There is a valley between the two. [See Fig. 12–7.]

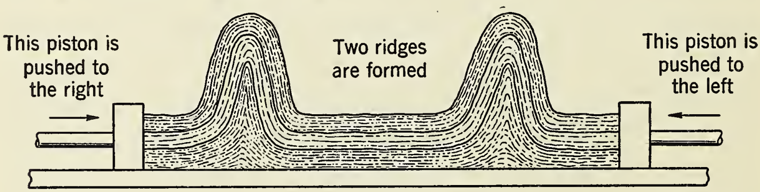


FIG. 12–7.

By repeating the experiment a third time, and making one sidewise push, or thrust, much harder than the other, we find that the highest folding occurs near the end receiving the greater push. [See Fig. 12–8.]

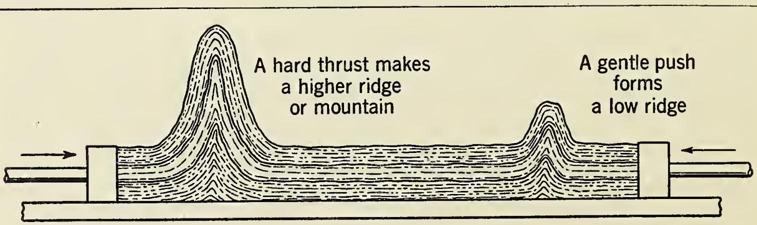


FIG. 12–8.

It is possible that some of the irregularities of the continents were produced by the terrific sidewise thrusts of the oceans on both sides of the continent. If one were to drive from coast to coast across the United States, he would find the hills and valleys just about as shown in Figure 12–9. You will notice that the highest mountains are near the deepest and largest ocean.

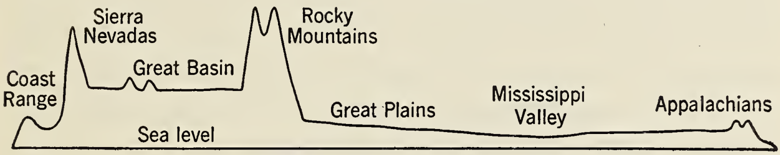


FIG. 12–9. We climb mountains, descend into valleys, and cross plains in going from San Francisco to New York.

179. How do volcanoes build up land areas? Some volcanoes are almost continually belching out steam, molten rock, and ash or cinder. In that way, a volcano may build up a huge cone. A volcanic cone may be fairly steep if the material thrown from the crater of the volcano consists largely of ash or cinder. If the volcano emits only *lava,* or molten rock, the cone will not be nearly so steep, since the lava flows slowly down the sides of the cone before it cools enough to become solid. It may flow in such manner for many miles. Enormous quantities of material flow from such craters. [See Fig. 12–10.]

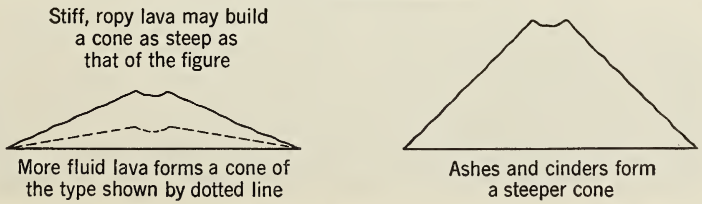


FIG. 12–10. Stiff lava forms a steeper cone than more fluid lava, but it is never as steep as a cinder cone.

Some volcanoes erupt only at intervals of several years. It was in A.D. 79 that the great eruption of the volcano Vesuvius (vė̇·sū′vĭ·ŭs) occurred. White-hot molten rock, or lava, flowed for miles in nearly every direction. The rain of volcanic ash buried Pompeii (pŏm·pā′yē), Herculaneum, and three other small cities on or near the Bay of Naples to a depth of many feet. From the ruins of Pompeii, we have learned much about the customs of the ancient Romans, and about the kinds of homes in which they lived. Parts of the ruined city have been dug up, or *excavated,* and visitors now wander about in the streets, gardens, and homes, seeing them much as they were in those early days.

Now a visitor to Naples can look at Vesuvius, about twenty miles to the eastward, and see the steam and smoke which is almost constantly arising from the crater. [See Fig. 12–11.] He may ride on a cogwheel railroad nearly to the top of this celebrated volcano. A short walk takes him down into the

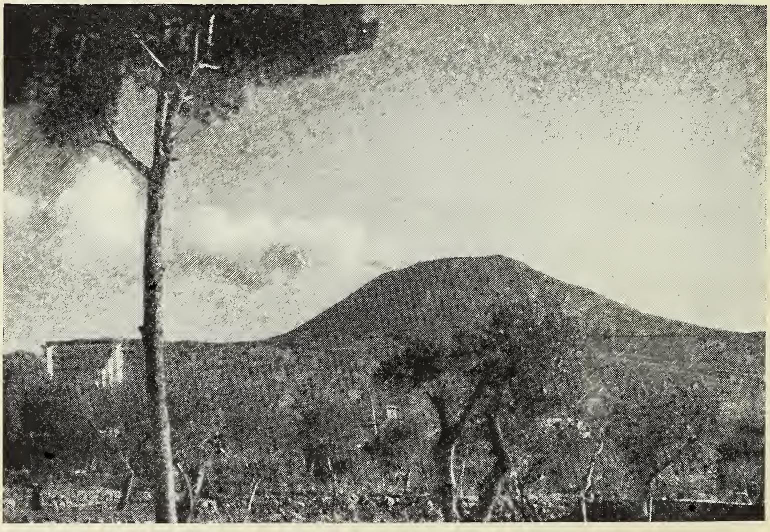


FIG. 12–11. A view of the volcano Vesuvius taken from the road from Naples to Pompeii. (*Ewing Galloway*)

old crater, fairly close to the new cone which was built up a few years ago. The fumes as they arise from this crater are illuminated by the glare of the fiery, red-hot lava beneath. Through small *fissures* in the sides of the cone, and in the floor of the old crater, small streams of red, gleaming lava are constantly oozing.

Some Italians living in the neighborhood of Mount Vesuvius have a rather risky method of making a living. If you give one of them a small coin, he will dip out a dab of hot lava, press the coin down into the lava, and in a few minutes hand it to you, embedded in a piece of cooled lava, as a souvenir. Of course he collects three *liras* (lē′räs) — about fifteen cents — from you for his trouble.

From time to time the activity of the volcano may increase, but it has never been so violent as it was in those early days when the five small cities were buried. The lower sides of the volcano are now covered with gardens, vineyards, and apricot orchards which extend up the mountain sides several hundred feet from the base of the volcano. The gardeners and fruit growers live there, because of the very fertile soil, apparently not much worried for fear that another destructive eruption may occur.

Etna, a neighboring volcano on the island of Sicily, is so huge that the circumference of its base is estimated to be about 100 miles. Stromboli, another explosive volcano, is called the " Lighthouse of the Mediterranean."

180. Can an explosive volcano cause great destruction? Prior to 1883, Krakatao (krä′kä·tä′ō) was a peaceful island near Java. Then occurred the most terrific explosion ever known to civilized man. Nearly one cubic mile of rock material was blasted away, including about one half of the entire island. Where one half of the island had stood, several hundred feet high before the explosion, the water after the

explosion was found to be 1000 feet deep. The noise of the explosion was heard 150 miles away, and windows 100 miles distant were broken by its force. A huge tidal wave, from 50 to 100 feet high, was formed. It spread rapidly over the Pacific Ocean, drowning some 35,000 persons who lived on near-by islands. The sea, for miles around, was covered with *pumice.* Volcanic dust was thrown so high into the air by the force of the explosion that some of it was carried entirely around the earth before it finally settled. For two years following the eruption of this volcano, this fine dust could be seen as it settled on ships. The most brilliant sunset colors were produced too as the dust particles in the air scattered the light rays and *diffused* them to form beautiful reds, oranges, and yellows.

Mount Pelée (pē·lā′) is an active volcano on the island of Martinique in the West Indies. In 1902 the city of St. Pierre was buried under a rain of ash and cinders from a violent explosion of Pelée.

Volcanoes like Vesuvius, Krakatao, Etna, and Pelée are known as the *explosive* type of volcano. The force of an explosion of one of these mountains seems to be caused by enormous quantities of steam. This steam is probably formed in the following way: underground water, from the ocean, leaks into the deeper parts of the volcano; the water comes into contact with the hot rock under the surface of the earth, and steam is created. The pressure of the steam becomes so enormous that an explosion finally occurs. Volcanic eruptions are sometimes preceded by earthquakes.

181. How did the Hawaiian Islands come into being? The Hawaiian Islands in the middle of the Pacific Ocean were built up almost entirely by volcanic action. They are merely the tops of huge volcanoes which have arisen from the ocean bottom, and were built up by extensive lava flows.

FIG. 12–12. This is the cone of Bromo volcano in the Dutch East Indies. In the foreground you can see the molten lava. (*Gendreau*)

From the floor of the ocean, about 30,000 feet deep, Mauna Loa and Mauna Kea, on the island of Hawaii (hä·wī′ē), rise to a height of nearly 14,000 feet above sea level. If we measure from the floor of the ocean, these volcanoes are nearly eight miles in height.

For the most part, these volcanoes are of the *nonexplosive*, or *quiescent* type. As the melted rock, or lava, rises higher and higher in the crater, it exerts more and more pressure on the sides of the crater. Finally the pressure becomes great enough to split the mountain sides and permit the lava to flow away quietly through the fissures that are formed. Little steam is formed, usually not enough to cause an explosion, unless the hot lava flows into the sea. [See Fig. 12–12.]

Kilauea (kē′lou·ā′ä), the largest crater in the world, is some sixteen miles from the city of Hilo, on the island of Hawaii. This region is now a national park. A hotel

known as the Volcano House stands on the rim of this giant crater. During the eruption of 1922, the whole crater was filled with molten rock. Now the rock has become solid, and rangers conduct tourists on a walk across the crater. Near the edges the traveler sees plants beginning to grow in the soils formed from the volcanic rock. As he walks on across the center of the crater, he finds a vast area of broken rock, in many places twisted into fantastic shapes. After a walk of about two miles, the traveler reaches the active pit, or what the natives call *Haumaumau* (hou·mou′mou). This pit is about 1300 feet deep, with sheer walls, and its floor space covers about 70 acres. When an ordinary eruption occurs, the rock at the bottom of the pit begins to glow; then it melts and becomes fiery red. The molten lava slowly rises in the pit, and sometimes it overflows and spreads over the old crater, covering it with a new layer of lava. In other cases, it does not reach the top, but seethes and boils, subsiding again as the period of activity ceases.

In former years the natives believed that their god Pele started increased activity in this pit when he was angered. In order to appease his anger, someone was thrown into the pit as a human sacrifice. This is an excellent example of the price that ignorant persons pay for costly and dangerous superstitions.

182. What were the effects of lava flows? Many mountains, which now show no signs of volcanic activity, must have been active volcanoes thousands and thousands of years ago. The land in the neighborhood of such mountains shows clearly that ages ago it was built up by the ash, cinders, and lava from volcanic action. Occasionally such a volcano, which is believed to be *extinct,* suddenly becomes very active. It has been what is called a *dormant,* or *sleeping,* volcano.

In some cases extensive lava flows come from cracks in the rock. No crater is formed, and no cone is built up. A fissure or a crack in the rock opens, and the molten lava flows out and spreads over large areas. There are many evidences in our western states that extensive land areas were built up by such lava flows, either from volcanoes which are now extinct or from rock fissures.

In some cases, the molten lava may not reach the surface. The fissure in the rock may extend upward vertically only part of the way to the surface. Lava is pushed upward and then flows sidewise between layers of rock. [See Fig 12–13.]

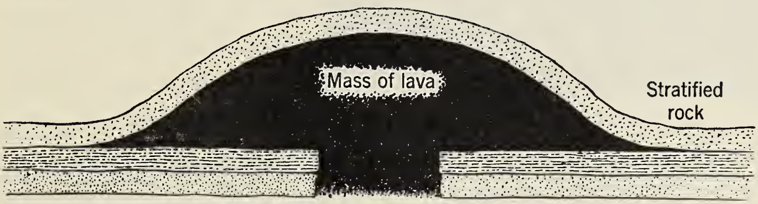


FIG. 12–13. Molten lava may be pushed up through cracks and in between rock layers.

Mounds or hills are formed in such manner in some localities. The Palisades on the New Jersey side of the Hudson River were formed by such *intrusions* (masses forced in), of molten rock, or *igneous* rock which are slowly pushed up between the shales and sandstones of that region. Now that the softer rocks have been worn away, the igneous rocks stands like perpendicular walls from 250 to 550 feet high. [See Fig 12–14.] The Giant's Causeway on the northern coast of Ireland is also a familiar example of the effect of such intrusion of molten rock. As the rock cooled, it split up into six-sided columns, some of which are 500 feet high. From Figure 12–15, you can see why it is known as the Giant's Causeway.

FIG. 12–14. The high perpendicular walls of the Palisades on the Jersey side of the Hudson River opposite New York City. The intruded rock forms many interesting patterns. If you can spend a day examining the rocks of the Palisades, you can learn much about their structure and formation. (*Free-Lance Photographers Guild*)

FIG. 12–15. Giant's Causeway, Ireland. The side of the cliff extending into the water is called the Wishing Chair. As a scientist, do you think this is a good name? (*Ewing Galloway*)

183. How do geysers build up land areas? A coffee percolator, with its small jets of liquid and steam, is much like a geyser. At the bottom of the percolator there is a supply of liquid. There is a column of liquid in the tube of the percolator. Water boils at a higher temperature than 100° C. when it is under a greater pressure than that of the air at sea level. The column of water in the tube of the percolator adds its pressure to that of the air pressure and thus raises the boiling point. When the higher boiling point is finally reached, some of the liquid is pushed out of the tube, and for a moment the pressure is slightly reduced. But steam forms immediately when the pressure is slightly reduced. You will recall that steam takes up about 1700 times as much space as did the water from which the steam was formed. The rapidly expanding steam pushes and forces jets of liquid up the tube so that it spouts out from the top with considerable force.

The geyser has a tube-like section that is many feet in length or depth. It has also an underground basin of water, which is heated by being in contact with very hot underground rocks. The water grows hotter and hotter until its boiling point is reached. Then the expanding steam pushes a huge jet of boiling water out of the tube. The force of the expanding steam may be great enough to throw many gallons of water to a height of from two hundred to three hundred feet. Some geysers spout for several minutes at a time.

Old Faithful Geyser, in Yellowstone National Park, erupts fairly regularly about once an hour. It gets its name because it has been erupting at about the same interval for many years. At each eruption, it throws out, or expels, about 22,000 barrels of water. Some geysers are larger and throw water to a greater height, but as a rule their eruptions occur

at very irregular intervals. The chief geyser regions of the world are found in Yellowstone National Park, Iceland, and New Zealand.

The hot waters of geysers naturally dissolve considerable mineral matter. The mineral matter in solution is expelled with the water. As the water flows away and cools or evaporates, much mineral matter is left, thus helping to build up land areas, but in a much smaller way than that of volcanoes.

184. Do hot springs build up the earth? From hot springs, in which the water is not quite hot enough to boil, the water flows away quietly. As it flows from the hot spring, much of the mineral matter which was dissolved in it is deposited, because both cooling and evaporation take place. Huge terraces have been built up by the hot springs of Yel-

Fig. 12–16. Jupiter Terrace in Yellowstone National Park is built up from limestone dissolved in hot water underground and then deposited by the hot springs as they cool. The formation shows beautiful colors. (*Union Pacific Railroad Photo*)

lowstone National Park. They consist largely of *calcium carbonate*, the same mineral that is found in limestone and marble. [See Fig. 12–16.] This material builds up much faster than that deposited by geysers. Some of the terraces are beautifully colored. It is interesting to learn that the colors are due to some *flowerless* plants known as *algae* (ăl′jē), which grow in water that may be as hot as 160° F., or even 170° F.

185. What are the results of earthquakes? Very often earthquake shocks precede or accompany volcanic eruptions. They sometimes occur, however, without any connection with volcanic activity. When an earthquake occurs, the earth trembles, shivers, or vibrates over a rather large area. If the earthquake is severe, it shakes down houses and wrecks large buildings. In some cases a huge fissure opens in the

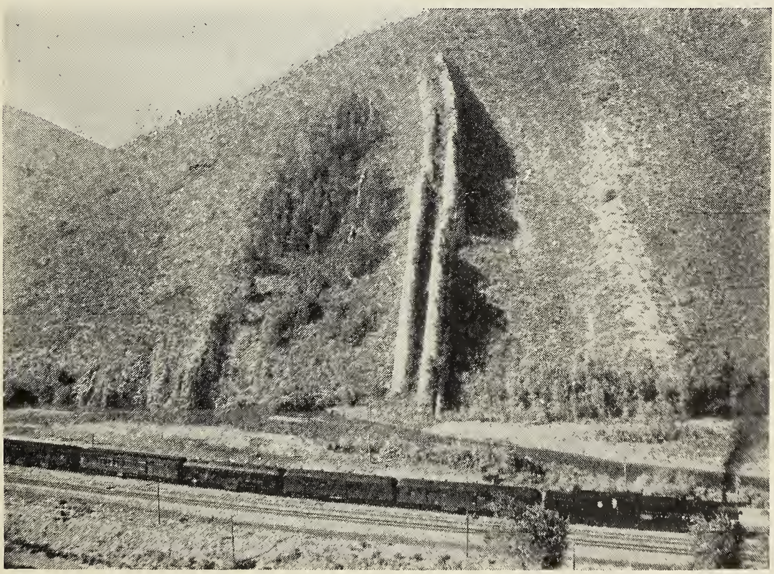


FIG. 12–17. The Devil's Slide is a natural rock formation in Utah. You can get an idea of its size from the train in the foreground. (*Union Pacific Railroad Photo*)

earth's surface. The land along one edge of the fissure may be pushed upward, hundreds of feet at times, to make a steep bluff or cliff where the land before was nearly level. Often the land on one side of a fissure slips down. Geologists call such a fissure in the crust of the earth a *fault line,* and the *displacement,* usually vertical, is a *fault.* Usually only a small part of the entire fault can be seen. The trembling of the earth may be caused by friction as the two edges of the fault line slip past one another. Earthquake shocks may sometimes be caused by falling masses in underground caverns. After an earthquake, a fissure may remain open permanently, or it may nearly close. Sometimes it fills up with molten rock or lava, which later solidifies. If the rock on either side is softer, it will wear away more rapidly than the igneous rock that was intruded, or forced in. The wall of such igneous rock forms what is called a *dyke.* Dykes are common in the mountains of Wyoming. The famous Devil's Slide may possibly be of such origin. Dykes may be vertical, or inclined at any angle. [See Fig. 12–17.]

Questions

1. What forces are at work elevating or building up the land areas?
2. Where does one find the highest mountain ranges in the Americas?
3. Is there a low central plain in South America which corresponds to the Mississippi Valley?
4. From the definition which you learned for burning, do you think that it is correct to speak of a volcano as a "burning mountain?"
5. Look up the definition of the word *dormant.* What do you think one means when he speaks of a dormant volcano?

6. Why is the volcano Stromboli known as the "Lighthouse of the Mediterranean?"

7. Men go down into the crater of Mount Popocatepetl (pō-pō'kä·tā'pĕt'l) in Mexico to dig sulfur which is deposited there. Do you think that work is particularly dangerous?

Some things for you to do

1. By questioning, find someone in your community who has gone through an earthquake. Write the story of this person's experience.

2. Read chapter 8 in Jean Henri Fabre's *This Earth of Ours* and report to the class on some dramatic or exciting part of this event.

3. With your teacher's aid, build a small model of a volcano out of sand. With a rounded stick, make a hole from the top nearly to the bottom of the model. Pour into the hole about two tablespoonfuls of ammonium dichromate. Set fire to the dichromate by touching it with the tip of your burner flame.

Think about these!

1. If you watch a muddy stream, you can see it carrying away particles of valuable soil. The stream may carry the soil into the ocean. What other forces can you think of that move soil from one place to another?

2. There is an old saying: "Dropping water wears away the hardest rock." Do you think that water can play a part in changing solid rock into particles of soil?

3. What is sand made of?

4. What animals move soil from one place to another?

Words for this chapter

Disintegrating (dĭs·ĭn′tė·grāt′ĭng). Reducing to fragments or particles.

Shale (shāl). A rock formed from clay that has been pressed together with great force.

Deposit. To lay down, or leave, as evaporating water leaves some substance which has been dissolved in it.

Spall (spôl). A fragment of broken rock.

Erode (ė·rōd′). To wear away, as water wears away land.

Erosion (ė·rō′zhŭn). The wearing away of rock or soil.

Sediment (sĕd′ĭ·mĕnt). Material deposited by water.

Levees (lĕv′ēz). Embankments which hold back water or floods.

Humus (hū′mŭs). The dark brown or black part of the soil, which has been formed by decaying plant or animal life.

CHAPTER 13 ——————— UNIT 6

What Forces Tear Down the Earth's Surface?

186. How do opposing forces work? We have been studying certain forces and agents which are at work lifting the continents above sea level. They are probably not so active today as they were in ages past, but the work is still in progress. The geologist who studies the earth's crust thinks in terms of thousands or millions of years, and he studies changes that have been exceedingly slow.

While the upheaval of the continents is going on, there are many agents that are constantly at work tearing down hills and mountains, and carrying them out to sea. These agents, too, work slowly, but they accomplish a great deal because they work almost all the time. Let us study first some of the agents that are *disintegrating* bedrock or solid rock, and then take up the study of those agents that are engaged in carrying away the particles which are formed.

187. What is weathering? The process of changing bedrock, or solid rock, into loose rock, or into tiny particles which are called *soil,* is known as *weathering.* Figure 13–1 shows the edge of a rocky precipice. At the top there is a layer of soil which was formed by the weathering of the bedrock. If you grind up a piece of sandstone rock into fine particles, nothing but sand is formed. Thus we find sandy soils formed by the weathering of sandstone. But if a piece of *shale* rock is powdered, or ground into fine particles, the product that is formed is clay. A soil composed of clay is formed by the weathering of shale and slate. The weathering of limestone forms a limy soil.

Soils formed by weathering may remain just where they were formed, or they may be transported by winds, running water, or glaciers to far distant points. During such transportation, various kinds of soil may be thoroughly mixed.

Fig. 13–1. As the bedrock weathers, soil is formed. Plants send their roots down into this newly formed soil, and they help the process of weathering. (*Courtesy U. S. Department of the Interior*)

Some farm lands are composed of a mixture of sand and clay which is called *loam.* If most of the mixture is sand, we have a sandy loam; if it is more largely made of clay, we have a clayey loam.

188. What causes weathering? Several factors are at work in the process of weathering:

a) *The air.* Suppose you take a hammer and break open a rounded stone taken from a brook or a field. You find that the color of the rock on the inside is decidedly different from the color near the outside edge of the broken surface. This surface layer seems to be discolored. In many cases it seems less compact, and it is probably softer than the unweathered portion. In some cases it is soft enough to crumble fairly easily. The oxygen of the air attacks the rock, in much the same manner that oxygen and moisture attack iron and convert it into iron rust, a product that crumbles up easily. The moisture present in the air also helps in the weathering of rock.

Carbon dioxide dissolves in water and forms what is known as *carbonic* (kär·bŏn′ĭk) *acid.* It is a weak acid, but, if given enough time, it dissolves some rocks, particularly limestone rocks. The caverns in such limestone regions as Indiana, Kentucky, Virginia, and New Mexico were formed by the action of carbonic acid, which first dissolves the limestone and then carries it away by means of underground streams. As the water evaporates, it will *deposit* the limestone. As it evaporates from the roof of the cave, it gradually builds down stony masses, or icicle-like structures in appearance, that are called *stalactites* (stȧ·lăk′tīts). If the limestone is deposited on the floor of the cave, it builds up irregular masses called *stalagmites* (stȧ·lăg′mīts). The two may continue to grow, as more and more material is deposited upon them, until they meet to form columns. [See Fig. 13–2.]

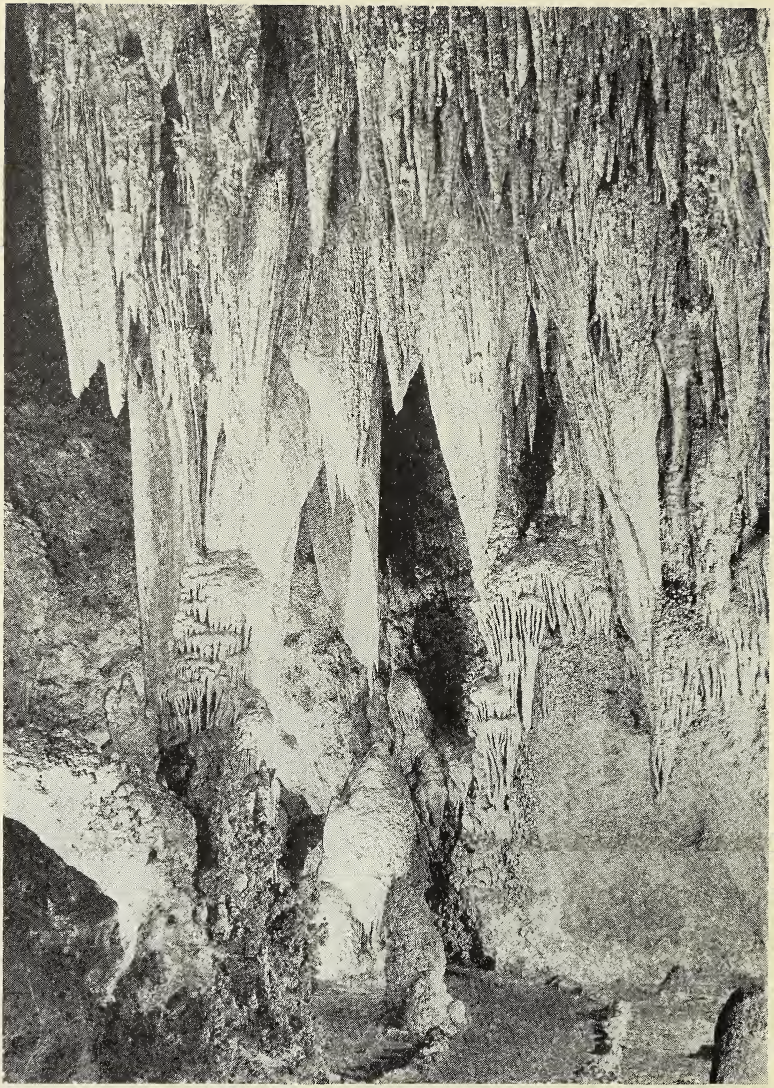


Fig. 13–2. As the stalactites build downward slowly from the roof of the caves, they sometimes meet the stalagmites, which are building upward. All kinds of fantastic forms and shapes are produced. Those shown here are in the Queen's Chamber, Carlsbad Cavern National Park, New Mexico. (*Courtesy U. S. Department of the Interior*)

If you wish to carry further your study of rock and soil, you may break off a piece of rock from some ledge, grind it up into small pieces, and then compare them, by the aid of a good magnifier, with the particles of soil found near the base of the ledge. Do you think that the sample of soil was formed, to a considerable extent, from the ledge of bedrock? Can you give a reason for your opinion?

b) *The heat of the sun.* Sometimes men digging a cellar for a new house find a boulder too large to be moved. What do they do? In some cases, they drill a hole in it and blast it with dynamite. In some cases it may be so near another house that they cannot run the risk of breaking the windows of that house by blasting. They then build a huge fire around the boulder to heat the rock to a high temperature. Then water is thrown upon it to cool it quickly. The rock expands when it is heated and contracts when it is cooled. Such a sudden change in temperature will cause fragments of rock to break off the surface of the boulder. By repeating the operation, the boulder may be broken up into pieces which are small enough to be carted away.

Through the thin layers of air near the mountain tops, the heat rays of the sun beat down with terrific force. The rocks are heated in the daytime, particularly on the outer surface. As the outer surface is heated, it expands more than the inner portion of the rock. Such unequal heating breaks the rocks into chips, or *spalls.* At night the rock cools off quickly, and contraction occurs. Such expansion and contraction, due to alternate heating and cooling, cause rocks to crack and break up into pieces. Piles of loose rocks are usually found at the base of a mountain or at the base of a precipice or cliff. How do you suppose they were formed? [See Fig. 13–3.]

c) *The freezing of water.* Suppose that a small crack develops in bedrock, from unequal heating and cooling. Water

FIG. 13–3. What causes the rocks to break away from the cliff and form huge piles near its base? (*Courtesy U. S. Department of the Interior*)

may flow down into a crack or crevice formed in this way. If the water then freezes, probably at night, it expands and enlarges the crevice, because ice takes up about 10 per cent more space than the water from which is was formed. The next day the ice may melt; then the water will run down deeper into the enlarged crack in the rock, freeze again the following night, and enlarge the split in the rock more widely. Alternate freezing and thawing play an important part in splitting up bedrock. Possibly you have observed the damage that freezing and thawing do to our streets and highways in winter.

d) *Plants and animals.* Look at Figure 13–4. You notice that the roots of a tree have grown down into the crevices of a ledge of rock. As the roots grow larger, they exert enough pressure to split the rock. On many stones one finds grayish-green plants which are known as *lichens* (lī′kĕnz). These scale-like plants attach themselves to rock masses, holding

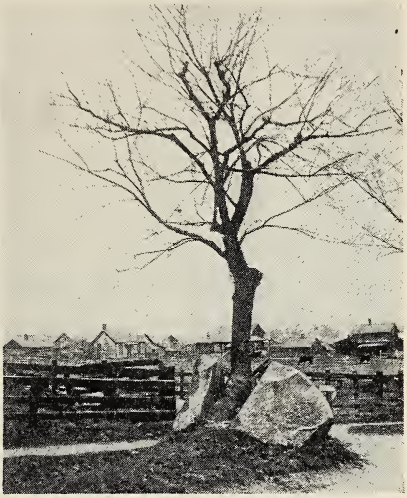


FIG. 13–4. The force exerted by a growing tree may be great enough to split a rock into pieces. It does not seem possible that a tender root or stem can exert such force, but it is not uncommon to have sidewalks lifted or pushed aside by the roots of trees. (*Photo by U. S. Forest Service*)

fast by means of a curious rootlike structure. An acid which they secrete helps to bring about the slow weathering of rocks. Animals sometimes carry away the surface soil and expose layers of bedrock to the agents of weathering. [See Fig. 13–5.]

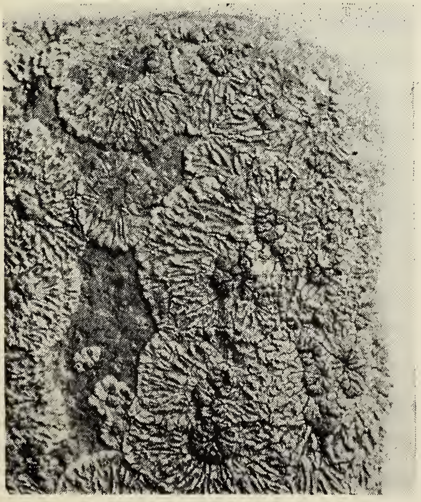


FIG. 13–5. If you examine a lichen with the aid of a microscope, you will find that it is really made up of two kinds of plants living together and each helping the other. The green parts supply the food, and the other parts of the lichen cling to the stone and make a home for both. (*Photo by E. B. Mains*)

189. How are rocks and soils moved and eroded? There are many agents at work moving the weathered soil, carrying it from one place to another, and eventually transporting much of it to the seas and oceans. Soil that remains where it was formed is called *residual* (rē·zĭd′ū·ăl) *soil*. The following are agents which move and *erode* soils:

a) *Animals as agents.* Earthworms bring soil from considerable depths up to the surface. Tons of material are moved every year by these animals. Burrowing animals, such as gophers, moles, and woodchucks, loosen up compact soil and transport it from one place to another. Beavers sometimes dam up streams and flood the surrounding areas, or they may divert a stream from its normal course. Man, too, in his engineering work, plays a considerable part in blasting rocks and in transporting rock materials.

b) *Winds as agents.* After rocks have been weathered, the winds may pick up particles of dust and sand and carry them for miles. You have read of the terrific dust storms that have occurred in certain parts of the United States. Not only does the dust in such storms blow into houses and become a nuisance, but the farmer loses some of the most fertile parts of his land. He is not likely to get his rich soil back again. It is deposited somewhere else where it may add fertility; but there is a chance it will not be wanted there.

In some places wind-blown sand accumulates in huge piles called *sand dunes*. [See Fig. 13–6.] The wind keeps picking up the sand from the windward side of the dune, carrying or rolling it up over the top, and then dropping it on the other side of the dune. Thus a dune travels forward. It may bury trees or houses that lie in its path.

Even the solid rock is attacked by the wind. As the wind blows against a ledge of rock, it gradually cuts it away. If the wind is carrying sand along with it, the rock is cut away

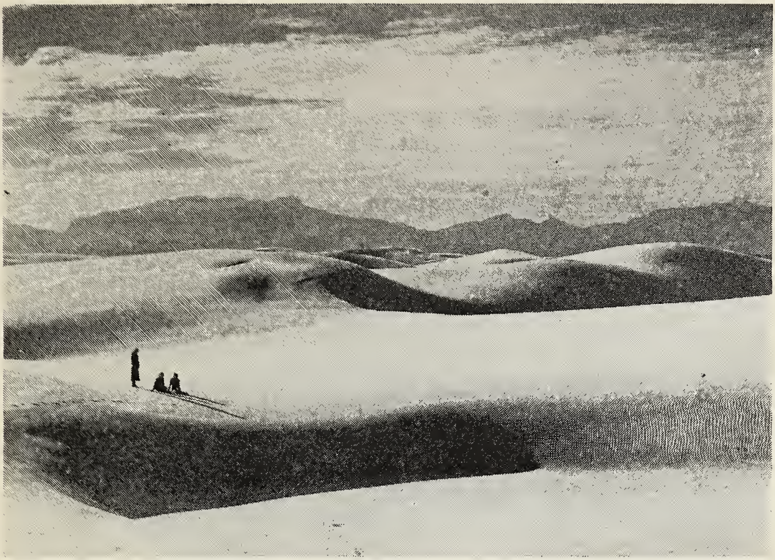


Fig. 13–6. Wind-blown sand may form dunes large enough to bury trees or houses. (*Courtesy U. S. Department of the Interior*)

much faster, because each tiny grain of sand with its sharp edges makes a good cutting tool which carves the rock into fantastic shapes. Possibly you have seen men cleaning the surface of a brick or stone building by means of a sandblast. Such a sandblast consists of a stream of wind-blown sand. Of course, the softer parts of the rock are cut away more rapidly than the harder portions. That explains why rocks in some desert regions may be carved so peculiarly. [See Fig. 13–7.] Glass in some lighthouses has to be renewed because the wind-blown sand makes it opaque, or clouded. This wearing away of rocks is a form of *erosion*.

c) *Running water as an agent.* Several thousand years ago Niagara Falls were seven or eight miles downstream from their present location. The water flowing over the precipice has cut it back, a few inches a year, and at the same time has formed the gorge of the Niagara River. The Horseshoe

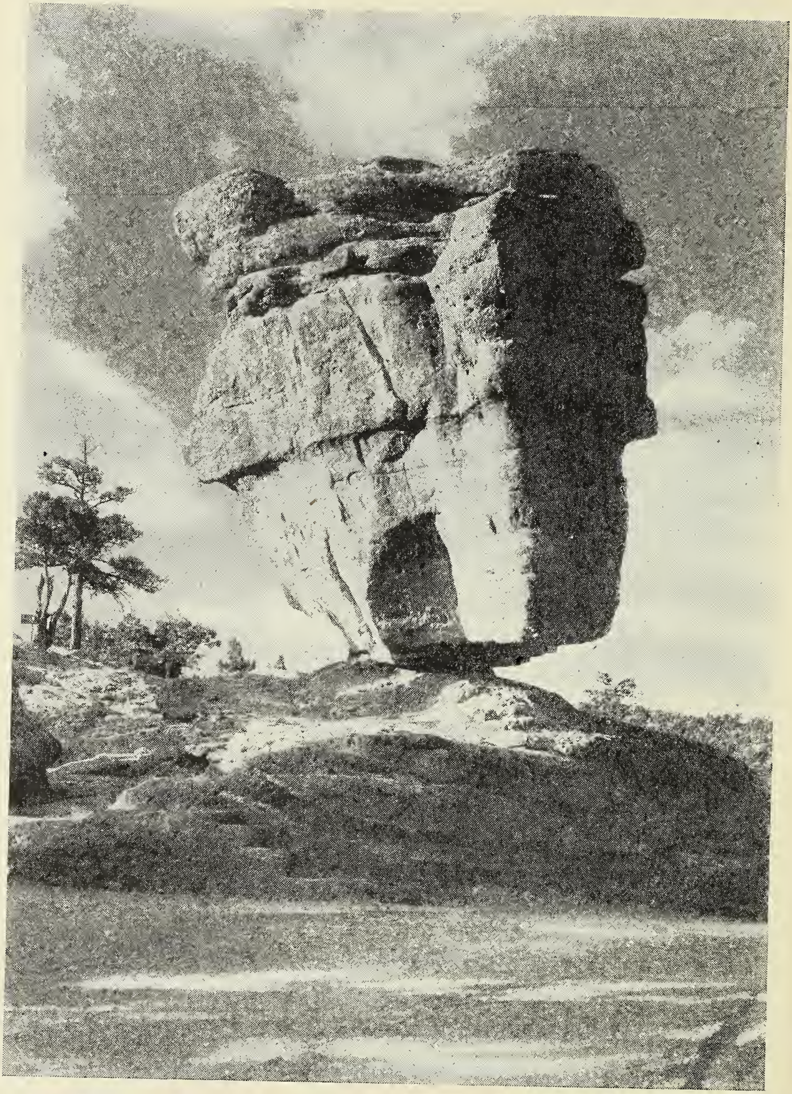


FIG. 13–7. Many of the rocks in the Garden of the Gods in Colorado are carved into strange shapes by the wind and the particles of stone which it carries. None of them are more interesting than the Great Balanced Rock. (*Courtesy Colorado Springs Chamber of Commerce*)

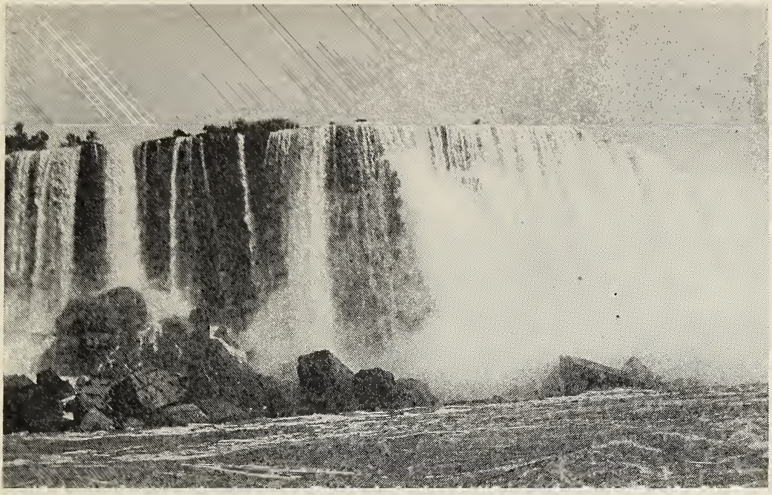


FIG. 13–8. The Horseshoe Falls of the Niagara River. (*Courtesy Chamber of Commerce, Niagara Falls*)

Falls are now moving upstream slightly faster than the American Falls, because so much more water flows over them each day. [See Fig. 13–8.]

For many thousands of years the Colorado River has been at work cutting and carving the Grand Canyon. This huge canyon is about 200 miles long, and in some places it is ten miles wide at the top. Down at the bottom of the canyon, at a depth of about one mile, one can see the yellow waters of the Colorado River, a half a mile in width, still at work day and night cutting away soil and rock particles and carrying them down toward the ocean. A river which carries a load of sand and fine gravel scours and cuts into earth and rock much more rapidly than a clear stream. The sand, gravel, and rough stones form the cutting tools with which the stream does its work.

Tens of thousands of years ago, after the glacial age, the waters of the great Columbia River flowed over a precipice

FIG. 13–9. The Great Dry Falls which were formed by the Columbia River. (*Courtesy Washington State Progress Commission*)

that is now known as the Great Dry Falls. Something happened to change the course of the river, and now the huge cliff known as the Dry Falls remains. [See Fig. 13–9.] Since the cliff, or precipice, over which the water flowed at one time, is 417 feet in height and about three and a half miles across, we can imagine that the cataract which flowed over it would have made Niagara Falls look somewhat like a pigmy, for the American Falls and the Horseshoe Falls each are about 160 feet high.

But we must not think only of such exceptional cases. Some of the most destructive work of running water consists in the carrying away of the soil from plowed fields, especially from sloping lands or hillsides. Suppose you watch a hard, dashing rain as it falls on a piece of gently sloping ground which has been freshly plowed or cultivated. You can then see just how water begins the work of erosion in the wearing away of the land. Some soil, which is fine and loose, begins

to roll down hill as it is pushed by the weight and pressure of the water behind it. This makes a slight valley, and more of the water runs down through the tiny gully thus formed. The small stream flowing through this gully carries more and more soil and soon cuts the gully both wider and deeper. It also cuts away the material upstream so that the gully is lengthened, too. At first the gully is *V*-shaped. Then it becomes larger and more rounded until the small valley becomes U-shaped.

Possibly another tiny rivulet meets the stream which you are watching, and the larger volume of water enables the two streams to wear away the soil still more rapidly. The fine, rich soil of that hillside is being carried away by the running water, and in time the land will be ruined for farming purposes unless some method is used to prevent erosion and conserve the soil. Figure 13–10 shows a hillside covered with small gulleys.

FIG. 13–10. Could this erosion have been prevented? (*Courtesy Soil Conservation Service*)

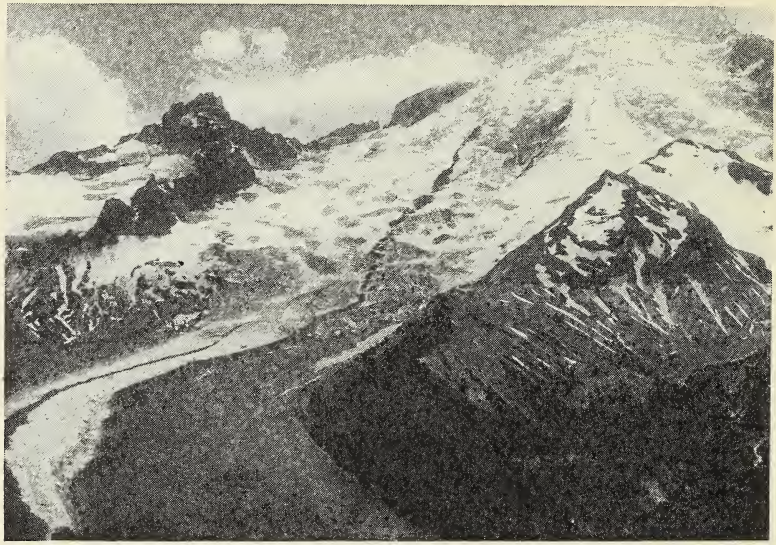


FIG. 13–11. This glacier is slowly moving down a valley between two mountain peaks. (*Courtesy U. S. Department of the Interior*)

d) *Glaciers as agents.* Have you ever seen a glacier high up in the valley of some mountain? [See Fig. 13–11.] The snowfields which feed such a glacier may be far up above the snow line, the elevation at which it is so cold that the snow does not melt. Such fields of granular snow — snow composed of grains or particles — are called the *névé* (nā′vā′) regions. The snow keeps falling until it sometimes reaches a depth of hundreds of feet. Such a huge weight of snow presses down upon the snow at the bottom of the pile with a force of many tons. Some of the snow melts under so great a pressure, and then freezes again as the glacier moves down the valley and releases the pressure. Thus the glacier, except for its upper parts, is changed to ice. The process is not different from that of making snowballs. You squeeze the soft snow until some of the snow at the surface melts under the pressure which you exert. It freezes again almost instantly

if you stop squeezing it. The icy glacier is slowly pushed down the valley, partially by the weight of the deep snow in the snowfields above, and partially by the expanding of water beneath the glacier as it freezes. A glacier creeps, flows, and slides downward, moving usually not more than a few inches in a day, but moving with *extremely great force*.

As a glacier moves down a valley, it drags or pushes soil and dirt along the bottom and also on the top along the sides. It also pushes large masses of soil, gravel, and large rocks along in front of it. Rocks and dirt fall down on top of the glacier and ride along with it. The scouring action of the glacier is most effective when rocks become embedded in its sides and bottom. Many rivers have their sources in the melting ice and snow at the lower end of valley glaciers. The swiftly flowing water coming from the glacier helps to

FIG. 13–12. The ice tunnels of Paradise Glacier, Rainier National Park, were formed in the same manner in which the one in the Rhone Glacier was formed. (*Courtesy U. S. Department of the Interior*)

carry still farther down the valley the small rocks and soil brought down by the glacier. There is an interesting tunnel which has been dug beneath the ice at the lower end of the famous Rhone Glacier. Large tunnels are also found under Paradise Glacier in Rainier National Park. [See Fig. 13–12.]

e) *Continental glaciers.* About twenty-five thousand years ago the climate in Northern Europe and in North America must have been *much colder* than it is today. The entire northern part of both continents was then covered with huge ice sheets, which gradually moved southward. No doubt the ice was thousands of feet thick. As this huge mountain of ice spread out, it moved with almost irresistible force, dragging along underneath it soil, rocks, and huge boulders. We find many scratches in the bedrock which show clearly the directions in which the ice sheet moved. Possibly we may call them the *tracks* left by glaciers. Sometimes rocks were ground up, making what is known as rock flour. Some large boulders, from a parent ledge near Hudson Bay, were brought down by the ice sheet to some parts of the United States. Much of the deep, fertile soil of our prairie states was

Fig. 13–13. The southern limit reached by the huge continental glacier crosses the Missouri and Ohio River Valleys. Did the glacier cover what is now your home? If you live in an area over which the great glacier moved, you may find some scratches which it made on exposed portions of rock. Did it leave a huge boulder in your back yard as a souvenir?

dragged here by this continental glacier, which extended nearly as far south as the Ohio and Missouri Rivers. Figure 13–13 shows the southern limit reached by the great continental ice sheet in North America.

Cape Cod, that curious armlike peninsula projecting out into the Atlantic Ocean from the eastern shore of Massachusetts, is supposed to have been formed by deposits from a glacier. In many places huge depressions were gouged out by the enormous masses of moving ice. The beds of the Great Lakes and many other lakes in the northern part of the United States were formed in this manner. It is difficult to realize the tremendous force exerted by these glaciers when they transport rocks and soil. As the ice melted, huge dams of materials were sometimes left. Then water filled the huge depressions gouged out and dammed up by the ice.

Rocks and soil which are carried by a glacier or pushed along in front of it, are left as *moraines.* The material dragged beneath the glacier is called a *ground moraine.* The material pushed along in front of a glacier, or deposited by the glacier where it stops moving forward, is called a *terminal moraine.* Valley glaciers scour the surfaces along their sides and the material scoured away forms *lateral moraines.*

In many localities the continental ice sheet left rounded masses consisting of soil and gravel in an unassorted mixture. They are known as *drumlins.* If a ridge is formed by a glacier it may be separated into *strata* (strā'tȧ) by the water that flows from the glacier. Such ridges are called *kames. Eskers* are formed from tunnels under the ice becoming filled with soil and gravel. When the ice melted, a ridge was left. *Sinkholes* are the result of large masses of ice with soil and rock around them; when the ice melted, a hollow was left.

A glacier may dam a stream or river and form a lake. [See Fig. 13–14.] It may, by its damming action, change the di-

FIG. 13–14. A valley glacier formed the breastwork of the dam shown at the right. As the glacier melted, it formed Moraine Lake. (*Courtesy Canadian Pacific Railway*)

rection in which a river flows. The Grand Coulee (kōō'lē) in Washington was once the bed of the Columbia River. The course of the Columbia River was diverted, leaving the Grand Coulee without water.

190. What becomes of transported soil? The soil which is carried by the agents of transportation is likely to find its way finally to the ocean, where it is deposited on the ocean bottom. It may make many stops along the way, some of them short visits and others very long ones. The swifter the current in a stream, the more dirt and soil it can carry. Very swift mountain streams can roll large boulders along the bottom, grinding them smaller and smaller as they roll along.

What happens when the speed of a heavily loaded stream is checked? It drops much of the load, or the matter which it had been carrying. When a stream at flood time overflows

its banks, its speed near the shores is checked decidedly. Here it drops some of the soil and gravel which it was carrying and deposits them upon the flats, or river-bottom lands. The larger particles are deposited first, and then the smaller pieces. Upon the bottom we find particles of coarse sand. Upon the top we find very fine particles of soil. In this manner water sorts out the soil and deposits it in strata. The next time the stream reaches flood stage, other layers are built up in the same manner. If the soil is later converted into rock, we call it *sedimentary* (sĕd′ĭ·mĕn′tȧ·rĭ) *rock* because it was formed from *sediment*. It may be called *aqueous* (ā′kwē̇·ŭs) rock from the Latin word *aqua*, meaning *water*, since water helped to form the strata. Because more mud is deposited near the banks of the river when it overflows, natural *levees* are sometimes built up by rivers. Along the Mississippi River men have built such natural levees to even greater heights. [See Fig. 13–15.]

The rice farmers of the lower Nile River in Africa get a new supply of fertile soil every year. At flood time, the Nile River picks up much fine soil from Central Africa and carries it northward. In Egypt the river overflows its banks, its

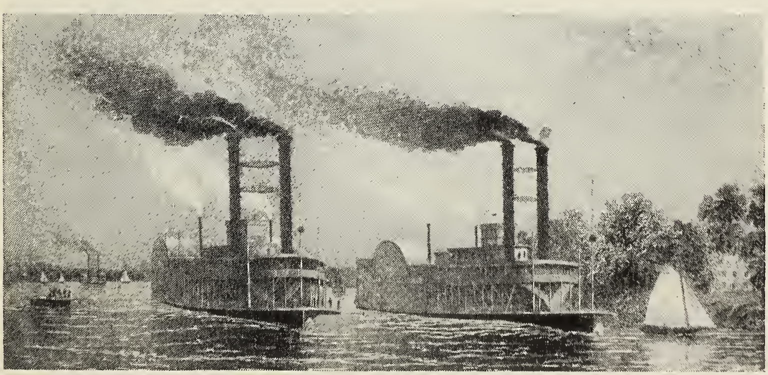


Fig. 13–15. What are some advantages of levees along the Mississippi River?

speed is checked, and the soil is deposited in layers upon the floodlands. This seems to be a good example of "robbing Peter to pay Paul."

The Mississippi River carries enormous amounts of soil, which is fed to it by the Missouri, the Ohio, the Tennessee, the Arkansas, and other tributaries. The name given to the fine soil carried by rivers is *silt*. The farm lands bordering on the Ohio, the Missouri, and other tributaries are being robbed of their fertility. Some of this silt goes to enrich the bottom lands along the Mississippi, some of it is used to build up the delta of the Mississippi, and some of it is carried far out into the Gulf of Mexico. The portion which goes into the Gulf of Mexico is lost forever as farm land, unless some giant force may at some future time lift the bottom of the Gulf of Mexico up above sea level.

191. What can we do to prevent loss of soil by erosion? When forests covered much of the eastern part of the United States, destructive floods like those which visited Hartford, Connecticut, and Pittsburgh and Johnstown, Pennsylvania, and many other cities, in the spring of 1936, were not so common or so destructive. In wooded areas snow melts slowly, and the trees prevent the water from running off quickly to swell the streams and rivers. The roots of the trees and other plants help to hold the soil and prevent its being carried away so easily. The leaves and *humus* of the forest floor act like a huge sponge which soaks up water and holds it. Now that so much land has been denuded of its forests, destructive floods are common, and much good soil is lost by erosion. What are some of the remedies?

a) *Reforestation.* Some of the land which has been stripped of its forests is of little value for farm purposes. That is particularly true of the Appalachian Highlands. In some countries the man who cuts down a tree must plant two

trees. Within the past few years, boys working in the CCC have planted thousands of trees. Such work assures a supply of timber for future generations, and the reforestation of certain lands helps to prevent the loss of soil by the ravages of destructive floods.

b) *Cover crops.* A wise farmer will refrain from planting corn on sloping land. Corn must be cultivated three or four times during its growing season to permit air to get into the soil. Such cultivation loosens the soil and almost invites the heavy rains to carry it away in rivulets, streams, and rivers. Such rolling lands should be seeded to grass and used for growing hay and as pasture lands for sheep and cattle. Grass is called a *cover crop* because it protects the soil. The roots of the grass hold the soil, and the grass itself helps to keep the

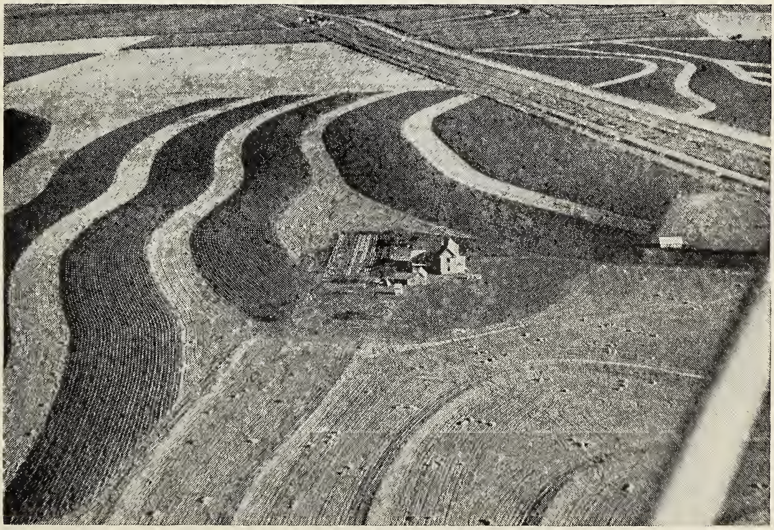


FIG. 13–16. This interesting airview of a farm in Texas shows the use of terraces and contour farming. These scientific farming methods conserve soil and water, and help to produce two abundant crops; this eliminates the danger of one-crop farming as well. (*Courtesy Soil Conservation Service*)

rain water from flowing away quickly. Some kinds of coarse grass will grow in sand. A shifting sand dune may migrate and cover trees or even houses. Beach grass planted on the windward side of a shifting dune may prevent it from moving any farther.

c) *Terraces.* In hilly regions where some sloping land must be farmed, it is possible to build the sloping land into terraces. [See Fig. 13–16.] Such land is suitable for growing fruits and vegetables, and for having vineyards. The rain falls on level ground on each terraced portion, and there is little loss of soil even from dashing rains. On sloping land where terraces are possible, the land should be ploughed and planted in rows encircling the hill or extending across it. This is called *contour farming.*

d) *Artificial storage lakes.* A number of years ago the city of Dayton, Ohio, was visited by disastrous floods. They carried away valuable soil from the surrounding farm lands and caused the destruction of city property, too. Artificial lakes or storage reservoirs have been built near the head waters of the streams and rivers that cause such annual floods. Such lakes and reservoirs store up the extra supply of water that falls during heavy rains, or the excess produced when heavy snows melt rapidly. Since the reservoirs can feed the excess water to the rivers slowly, destructive floods and soil erosion are both prevented.

In this section we have mentioned some of the things that man can do to preserve his fertile soil which is his heritage. It is well to remember, too, that while we are conserving our soil, we are also preventing destructive floods. We may be building artificial lakes that make centers for summer colonies. In some cases the water stored in lakes or reservoirs may be used to supply water power. Stored water is useful, too, for irrigation.

Questions

1. What are some of the chief causes of the weathering of rocks?

2. What are some of the causes of erosion?

3. By what methods is soil transported from place to place?

4. How can geologists tell in what direction a continental glacier was moving tens of thousands of years ago?

5. Suppose that you own a farm on a hillside. What steps would you take to keep the heavy rains from taking away your rich soil and giving it to your downstream neighbor?

6. If you own a farm that is hilly or mountainous, in what particular type of agriculture would you engage? Why?

7. Why are the Horseshoe Falls moving upstream faster than are the American Falls?

Some things for you to do

1. Crack up a small round stone. Examine its interior and compare it with the outside.

2. Grind up some limestone, by means of a mortar and pestle, or break it up with a hammer. Grind up also a piece of shale and a piece of sandstone. Mix some of the powdered shale with water. Does it resemble clay? Mix the three of them. Does the mixture resemble any soil that you have ever seen?

3. Break off a piece of rock from the face of a ledge. Grind it up into rather small pieces. Use a microscope to compare the fragments with some soil that you find at the base of the ledge. What do you conclude about the origin of that soil?

Think about these!

1. Do you think the comparison "as cheap as dirt" is a good one?

2. What valuable possessions of yours have come out of the earth?

3. What are some of the things that we would have to do without if men had never learned to extract oil from the earth?

4. If man wastes the mineral wealth that is found in the earth, how can he replace the minerals?

Words for this chapter

Stratification (străt′ĭ·fĭ·kā′shŭn). The process of depositing material in strata, or layers.

Decomposition. The process of breaking up a compound into its elements.

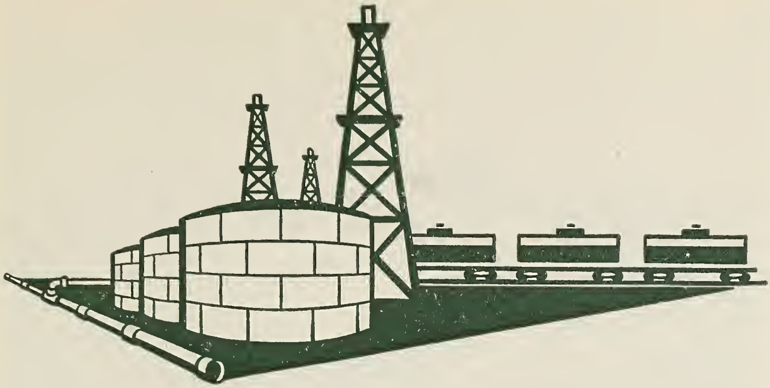
Nitroglycerine (nī′trō̇·glĭs′ẽr·ĭn). A liquid which explodes violently when it is made to vibrate or is heated very highly.

Potassium (pō̇·tăs′ĭ·ŭm). A chemical element necessary for the proper growth of plants.

Phosphorus (fŏs′fō̇·rŭs). A chemical element needed for the growth of living things.

Nitrate (nī′trāt). A combination of elements including nitrogen. It is used as a fertilizer.

Phosphate (fŏs′fāt). A combination of elements containing phosphorus. It is used as a fertilizer.



CHAPTER 14 ______________ UNIT 6

What Treasures Are in the Earth?

192. Why is soil part of a country's wealth? From our earliest childhood, we have seen plants growing in soil. But not all plants grow in soil. Some grow in fresh water, and there are many seaweeds which grow in salt water, too. On a small scale, man has begun to grow plants in water to which chemicals have been added. It is known as the *hydroponic* (hī′drō·pŏn′ĭk) method. [See Fig. 14–1.] In spite of such efforts, however, we can safely say that without soil and farm lands, man would not grow many plants. He certainly would not grow enough to keep the human race from starving. Without plants to make food for them, animals cannot live. Therefore we must conclude that much of the wealth of any country comes from its soil.

In the preceding chapter we learned that soil is being made constantly, but we found, too, that such soil is carried from

FIG. 14–1. This student is learning to grow plants without soil. What are some advantages of hydroponics? (*Courtesy Antioch College*)

one place to another by running water, winds, and glaciers. We learned, too, that man's destructive habits are responsible for many of the losses of fertile soil, and that he can conserve his soil by reforesting and by sowing seed for grass and other cover crops.

Possibly you have heard someone use the expression "as cheap as dirt." But really the dirt and the soil of the earth are worth more than all the gold, silver, and diamonds. Even sand, which is so abundant, is not to be ignored. It is put to dozens of different uses, from the making of sandpaper, mortar, plaster, and concrete, to the manufacture of glass. Clay is another product which one is likely to think unimportant because it is cheap and abundant. Not only does clay help to make soil fertile, but also it supplies the raw material which man uses in making cement, brick, tile, and some pottery.

A man who owns a farm and keeps the soil fertile can reap harvests from the land year after year. Even if a hurricane destroys a crop one season, the farmer may be more fortunate the next year. A farmer may feel very fortunate if he leases his farm to an oil company and they " strike oil " on his farm. Of course he is fortunate, too, but he needs to remember that all the oil may be exhausted in a few years, and that *he cannot replace that type of wealth.*

193. What is the source of coal? Thousands and thousands of years ago, the forests of the earth were far more extensive than they are at present. They grew much more luxuriantly, too, and the plants were different from those we know today. Millions of tons of plant materials were dropped annually by the forests. In periods of great floods, these were covered by soil and rock. When the beds of organic materials were folded and pressed by the crumpling and folding of the rocks, they were put under tremendous pressure, and they were probably subjected to great heat. It seems probable that the beds of coal found in the earth

FIG. 14–2. Traces of leaves like this in coal seem to prove that coal was formed from plants. Do you know what such imprints and remains are called? Such strange remains are more common in soft coal than they are in hard coal. In the latter they were doubtless destroyed by heat. (*American Museum of Natural History*)

were formed in that manner: the action of heat and pressure turned the plant materials into coal. In some of the beds of brown coal there are many evidences that coal was actually formed from plants. Traces of objects similar to leaves and stems can be seen in the layers of the coal. [See Fig. 14–2.]

194. Where is coal found? In several of the western states of the United States *brown coal* is found. The map shown in Figure 14–3, gives us a good idea of the extent of the coal fields in the United States. In many of the states there is also a supply of what is called *soft coal,* or *bituminous coal.* It shows evidence of *stratification.* In Europe, many countries have extensive coal fields. Coal has been mined in England, France, and Germany for many years.

Hard coal, which is commonly called *anthracite,* shows no stratification. It appears to have been changed so completely by heat and pressure that all signs of its having been formed in layers, or of its having come from vegetable matter, have

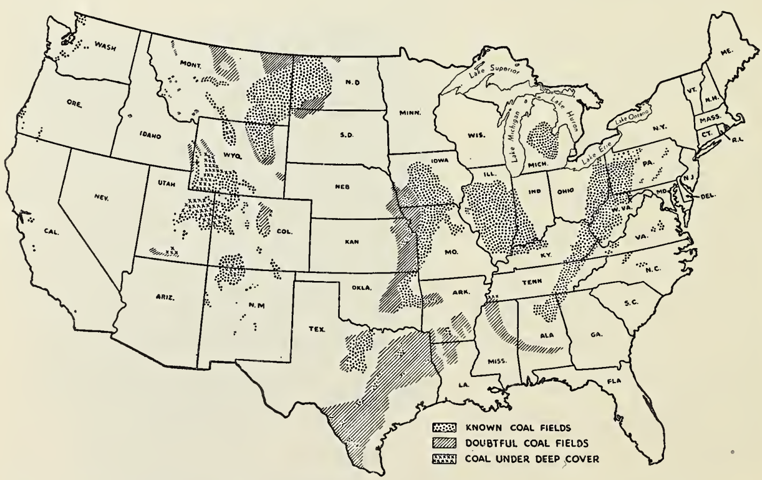


FIG. 14–3. General distribution of coal fields in the United States.

been destroyed. Nearly all the hard coal produced in the United States comes from the state of Pennsylvania. Very rich beds of hard coal have been discovered in China, but they have not as yet been extensively mined. One sometimes wonders what would happen if we were deprived of our supply of coal. In fact, it is so widely used as a fuel and in the industries that the "Old King Cole" of our nursery rhymes actually becomes the "Old King Coal" of modern industry.

195. What is the source of petroleum? Some scientists believe that petroleum also has its origin in plant materials. Possibly it was formed by the partial *decomposition* of plants. No one actually knows just how it was formed. There is also a theory that petroleum is formed from certain compounds produced by the uniting of carbon with some metal. Petroleum may have been formed by the action of water on such compounds.

196. Where is petroleum found? In the United States, petroleum was first discovered in western Pennsylvania in the vicinity of Oil City. As men learned more of its value and found many uses for it, the search for petroleum widened. It has been found in considerable quantities in many states. Among them are West Virginia, Ohio, Indiana, Illinois, Oklahoma, Kansas, Louisiana, Montana, Texas, and California.

Outside the United States, the oil fields of Mexico and Venezuela are well known. Wells are being drilled in Alberta, Canada. Petroleum is found in Iran and in Rumania. An abundant supply is found in areas near the Caspian Sea.

In some places petroleum seems to be present in underground streams. In other localities it seems to be present in underground reservoirs. Sometimes *natural gas,* an excellent fuel, is found with the crude petroleum. Some wells

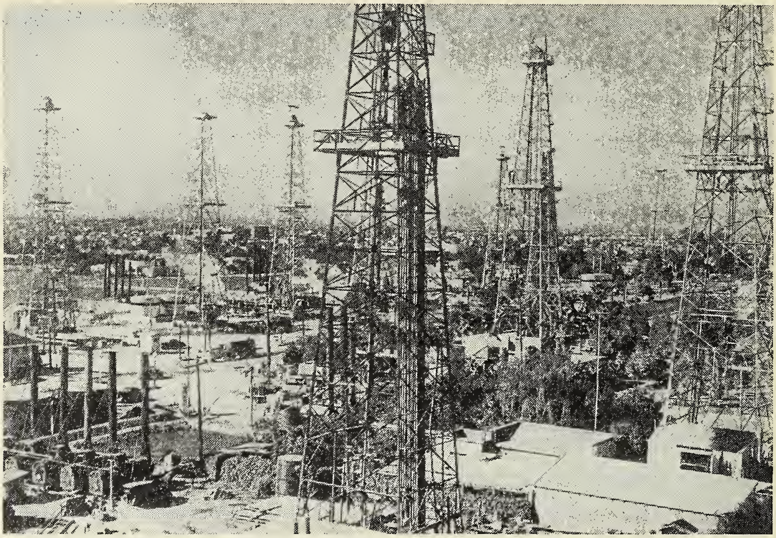


FIG. 14–4. Tall derricks in an oil field. (*Courtesy American Petroleum Institute*)

produce no natural gas at all. In some cases, the crude oil seems to float on the surfaces of reservoirs of salt water. [See Fig. 14–4.]

197. How do men get petroleum? In some cases the first step in drilling an oil well consists in driving an iron pipe about ten inches in diameter down through the soil to the bedrock beneath. By the use of a drill and a stream of water, the soil from inside the pipe is removed. This iron casing keeps the dirt from caving in and closing the hole. Then the drilling begins in earnest. A drill about three feet long, and shaped like a huge chisel, is lifted by a long *lever* (lē′vẽr), a bar used to pry something up. The drill is then dropped. It cuts a hole from six to eight inches in diameter down through the solid rock; the operation is repeated again and again. Very often a rotary drill is used to bore a hole down into the rock. In some places the oil is found at a depth of

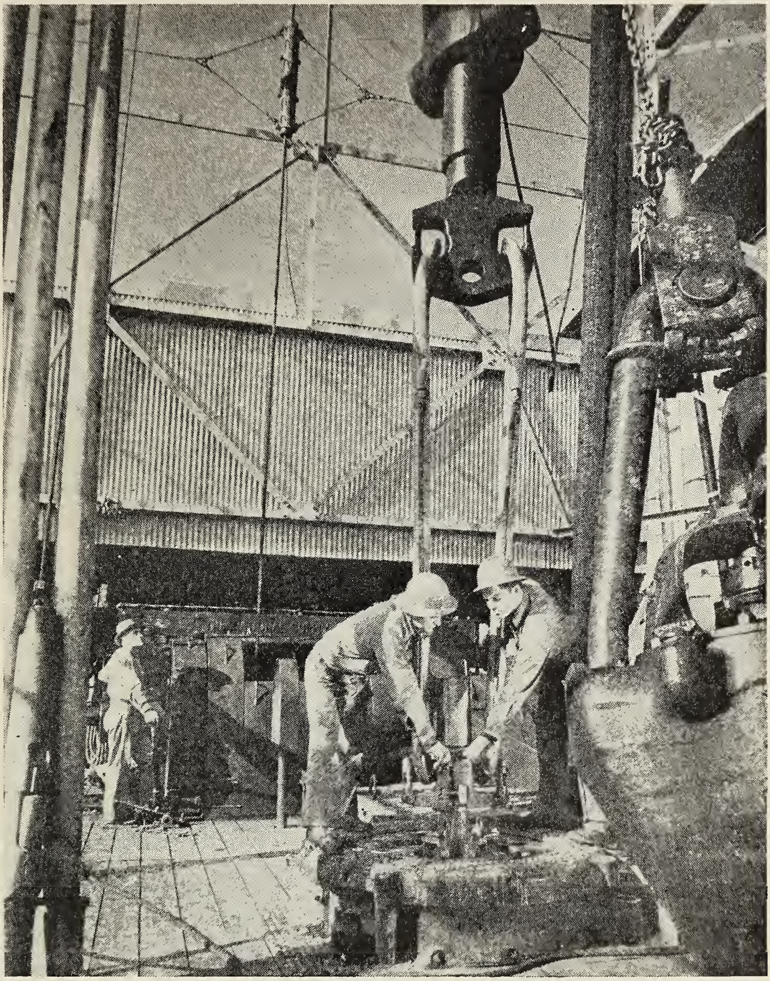


FIG. 14–5. This is the top of a modern oil well. The men are drilling for oil. Notice the metal hats which look like soldiers' helmets. What are they for? How much do you think it costs to drill an oil well? How do oil companies know where to drill their wells? Sometimes in drilling a deep well, the drill may become separated from the rods and pipes to which it is attached. Then the men must start "fishing" for the lost drill. (*Courtesy Texas Co.*)

only a few hundred feet, but in other localities the well must be drilled to a depth of several thousand feet in order to find oil. Wells have been drilled more than two miles deep. [See Fig. 14–5.]

When the crude oil is reached by drilling, some *nitroglycerine* is lowered into the hole and exploded, to break up the rocks at the bottom of the well and to permit the oil to flow more freely. If gas is present in the well, the petroleum may gush out from the well and flow at the rate of a hundred or more barrels daily. If no gas or other source of pressure is present, the oil must be pumped from the well.

198. What is the nature of petroleum? Crude oil, or petroleum, may be greenish-black, brownish-black, or nearly black in color. Much of it has a rather disagreeable odor. Generally it is less dense than water and floats on the surface of water. When the drill " strikes oil " and much gas is present, the oil gushes out, and a great deal is wasted before men can get the well under control. Such wasted oil flows out into the streams and rivers. It may catch fire, and the river may " burn " for miles of its length. Modern methods generally prevent such losses and conserve oil.

Petroleum is a mixture of several different liquids, which can be separated from one another because they boil at different temperatures. *Naphtha* (năf′thȧ), for example, boils at a low temperature. At a higher temperature, *gasoline* boils and is condensed to liquid gasoline. *Kerosene* and various *lubricating oils* have a still higher boiling point. Other products obtained from petroleum include *petroleum jelly, paraffin, fuel oils,* and *coke.*

199. What are some of the uses of petroleum? Dozens of valuable products are obtained from petroleum. In fact, it is so valuable that nations have risked going to war in order to gain control of rich oil fields. Probably the most valuable

of all the products is gasoline. Billions of gallons of gasoline are used every year to drive our airplane and automobile engines. Kerosene, too, is a valuable product.

Machinery does not run well unless it is lubricated frequently. Much of the oil used to lubricate machinery is obtained by refining crude petroleum. That portion of the oil which has little or no value for lubricating purposes finds use as fuel oil. Paraffin is used in insulating electrical wires, in making candles, and for many other purposes.

200. Where is iron ore found? The iron mines of Pennsylvania have been worked for years. Other states that have extensive iron mines are West Virginia, Alabama, Ohio, Missouri, Michigan, and Minnesota. In Europe rich ores of iron are found in England, Sweden, France, Belgium, and Germany.

201. How is iron ore mined? Iron ores vary a great deal in color and compactness. Some ores are reddish in color,

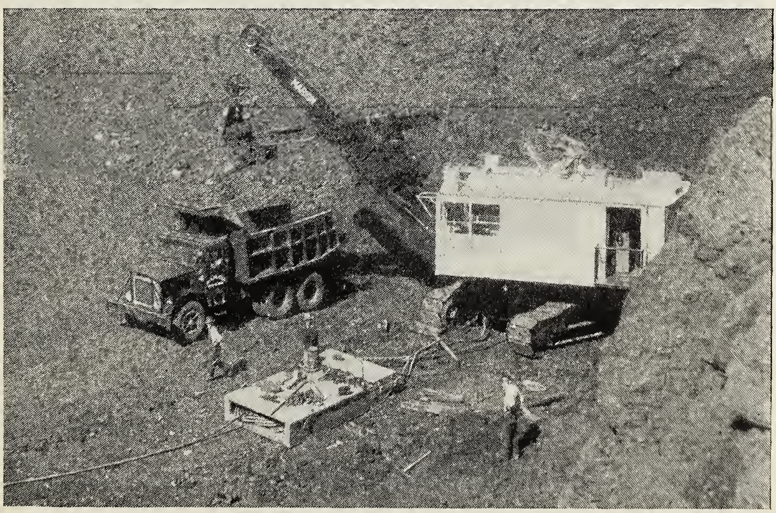


FIG. 14–6. Can you explain why strip mining is less expensive than shaft mining? (*Courtesy The Marion Steam Shovel Co.*)

others are yellow, still others are brown, and some are grayish-black. Some ores are hard and must be drilled full of holes and broken apart by means of explosives. Some ores crumble to a powder which resembles iron rust. Nearly all the iron ores are compounds made up of oxygen and iron.

Ores are sometimes found near the surface, but in other localities the ore may be hundreds of feet deep. If the ore is near the surface, the mining is not unlike the quarrying of rock, with which you are probably familiar. In northern Minnesota, steam shovels are used to strip away the earth and soil which cover the iron ore to a depth of some twenty to forty feet. [See Fig. 14–6.] The iron ore beneath the soil is so loose that it can be dug up with steam shovels. Temporary railroad tracks are laid down in the mines themselves, and the ore is loaded upon freight cars directly from the steam shovels. In no other place in the world can iron ore be mined so cheaply. This method is called *strip mining*.

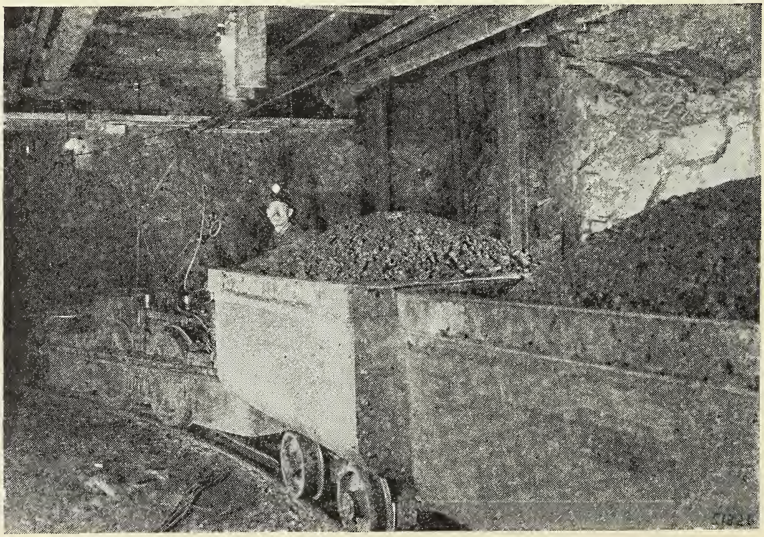


Fig. 14–7. The interior of a shaft mine. Iron ore is carried out of the mine in these little cars. (*Courtesy U. S. Bureau of Mines*)

When the iron ore lies several hundred feet underground, a shaft, which is like an elevator shaft, is sunk down to the beds of ore. Then tunnels branch off from the bottom of the shaft into the iron ore, in much the same manner that streets branch off from a city square. From these tunnels the iron ore is mined and loaded into small metal cars which are hauled, by electricity, upon narrow tracks laid along the floors of the tunnels. When they reach the bottom of the shaft, they are hoisted to the surface of the earth by means of heavy cables. This method is *shaft mining.* [See Fig. 14–7.]

202. How do we get iron from iron ore? Most of the iron ores consist largely of iron and oxygen. To get the iron from such ores, one must find some way to get rid of the oxygen. It is possible to do this if we can find some element that is more greedy for oxygen than is the iron of the ore. Coke, which is made by heating soft coal in huge ovens, consists largely of carbon. When iron ore is heated with coke in an enormous furnace, the hot carbon of the coke steals the oxygen away from the iron ore. The melted iron which is left after the oxygen is taken from it sinks to the bottom of the furnace. It is tapped off and let flow into molds where it hardens; or else it is made directly into steel. [See Fig. 14–8.]

From iron secured in this manner, all sorts of cast-iron implements are made. Much of the iron is made into steel. Can you name at least ten things that are made of iron or steel? In normal times, the United States makes at least 30,000,000 tons of steel every year. That means about 500 pounds for every man, woman, and child in the United States. Can you tell how and where you use or come into contact in any way with 500 pounds of iron during a year?

203. What are some common metals? (*a*) *Aluminum.* This metal is found in common clay, but the mineral from which it is extracted consists of aluminum and oxygen. We

FIG. 14–8. This picture shows two huge modern blast furnaces which are used to remove iron from its ore. In what ways is iron useful to you? (*Courtesy Carnegie-Illinois Steel Corp.*)

cannot use carbon to take the oxygen from it, because aluminum is more greedy for oxygen than the carbon is. A little more than fifty years ago, Charles Martin Hall worked out a process of decomposing aluminum ores (separating them

into different elements) by the use of electricity. Hall's process, which he invented shortly after he had graduated from Oberlin College, reduced the price of aluminum so much that it came to be used in making chairs, cooking utensils, parts for airplanes and automobiles, paint, and dozens of other things.

b) *Copper.* This metal was known to the ancients. The Egyptians, the Greeks, and the Romans all used copper for making bronze. Copper is sometimes found alone, not in combination with oxygen or anything else. More often it is found combined with sulfur, or with some other elements. Our leading copper-producing states include Montana, Michigan, Arizona, Nevada, and Utah. One mine in northern Michigan, which has been producing copper for years,

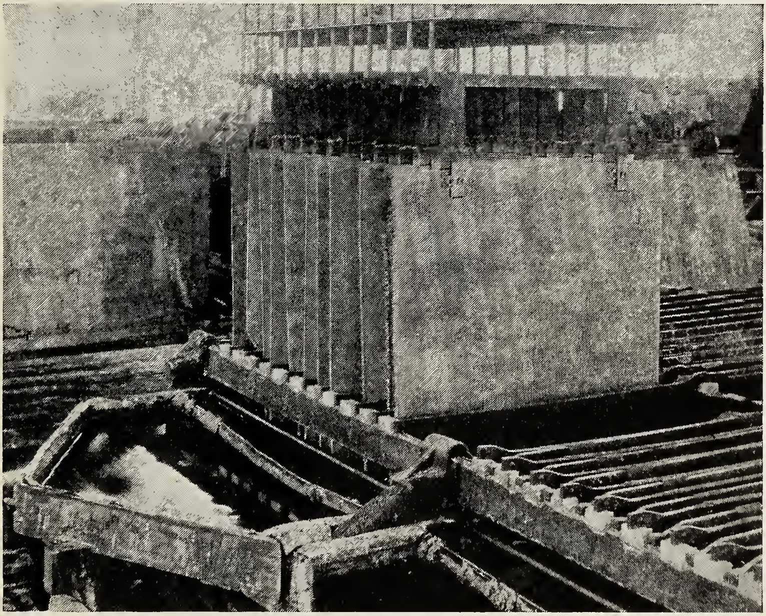


FIG. 14–9. Using electricity to make copper which is 99.999 per cent pure. The huge sheets weigh several hundred pounds. (*Courtesy Copper and Brass Research Association*)

is over a mile in depth. Copper is used in making both brass and bronze. Wires used for conducting electric currents are generally made of copper, although aluminum is sometimes used. [See Fig. 14–9.]

c) *Zinc.* Various ores of zinc are found in Missouri, New Jersey, and Montana. If you ever tried to make an electric battery, you probably used a zinc rod for the negative plate of the battery. Iron is a useful metal, but it rusts completely in moist air. If iron is thoroughly cleaned and then dipped into a bath of melted zinc, the zinc will stick to the surface of the iron and form a fairly even layer upon it. This process is known as galvanizing, and the product is known as *galvanized iron.* The layer of zinc keeps the iron underneath from rusting. One of the compounds of zinc is used extensively as a base for white paint.

d) *Tin.* This metal, too, was known to the ancients. The early Phoenicians (fē·nĭsh′ăns) sailed from their homes on the eastern coast of the Mediterranean Sea as far westward as the British Isles in order to get the "tin stone," or tin ore, which was found in Cornwall, England. Tin ore is also found in the East Indies and in Bolivia. Coke is used to remove the oxygen from the "tin stone," in much the same manner that it is used to take the oxygen from the iron in iron ores. *Tinware* is made by cleaning sheet iron thoroughly and then dipping it into a vat of melted tin. A thin layer of tin sticks to the surface of the iron and protects it from rusting. Tinware is used in making tin cans which are so important in the canning industry. Tin is the only common metal which is not mined in quantity in the United States. Although we do not produce much tin, yet we are the largest users of tin in the world. You can easily understand why that is true if you look over the canned goods in any grocery store.

e) *Lead.* The most abundant ores of lead contain lead

and sulfur. Lead ores are found in Colorado, Montana, Utah, and British Columbia. This metal is used widely in making the plates for storage batteries. Some lead is used for making lead pipes and as a covering for bundles of telephone wires. Large quantities of lead are used in making white lead for paints. [See Fig. 14–10.]

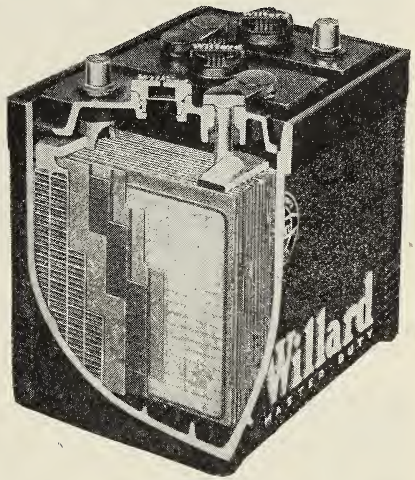


FIG. 14–10. This cutaway view of a storage cell shows the lead plates. It would be hard to get along without a storage battery in an automobile. It supplies energy for the horn, the lights, the self-starter, and the spark used to explode the gas mixture which drives the car.

204. What are the so-called precious metals? (*a*) *Gold.* To many persons the word *gold* seems to have a magic sound. Nations have made wars to secure a supply of the metal. In 1849, there was a great rush to California. Gold had been discovered there. Men took their families and trekked westward across the plains and deserts. All the property a family owned was loaded into a covered wagon in which the long trip was made. [See Fig. 14–11.] Many died of hardships, and others fell victims of the arrows of hostile Indians. Some reached their destination and staked out their claims. A few grew rich by panning gold (separating gold from earth by washing it in a pan), but a much larger number of persons were less successful. [See Fig. 14–12.]

Fig. 14–11. Many pioneers crossed the continent in covered wagons. Some of them went to find gold. Others were looking for new opportunities for living.

Fig. 14–12. The dredge replaces the pick and shovel for mining gold today. The panning, too, is on a larger scale. (*Courtesy U. S. Bureau of Mines*)

In 1900, gold was discovered in Alaska. Then a new gold rush to the Klondike was begun. Until gold was discovered in Alaska, no one cared particularly about the exact location of the boundary line between Alaska and Canada. As soon as the discovery was announced, boundary disputes arose between the Canadians and the Americans. The disputes were finally settled by a Joint High Commission consisting of Americans, Canadians, and English. These examples of reckless rushing after gold illustrate very well the greed that man has always had for this yellow metal.

Important places where gold is found are California, Colorado, Utah, Alaska, Australia, Canada, South America, and South Africa. No one has ever found very large quantities of it in any one place. If it were as common as sand, it would not be particularly valuable. Because it is scarce and durable it is used in making money and jewelry. It is particularly valuable because it does not rust or tarnish.

b) *Silver.* This metal is more widely distributed than gold, but is uncommon enough to be called a *precious* metal. Mexico, Utah, Peru, Montana, Ontario, British Columbia, Idaho, Arizona, British India, New South Wales, Nevada, Colorado, and several European countries produce silver.

Our silver coins are 90 per cent silver and 10 per cent copper. *Sterling silver,* which is 92.5 per cent silver, is used in making jewelry and tableware. *Silver-plated ware* is made by coating some less expensive metal with silver.

c) *Platinum.* Most of the platinum found in the world comes from the Ural Mountains of Soviet Russia and from Colombia in South America. It is scarcer than gold, and usually it is more costly. It is used in industrial operations where a metal that does not tarnish or rust is needed. It is not easily attacked by chemicals. Much platinum is used in making fine jewelry.

205. What precious stones come from the earth? From the earth as a treasure house, man gets a supply of precious stones, such as rubies, sapphires, emeralds, and diamonds. The diamond mines of India have long been producing stones of good quality. More recently the diamond mines of South Africa were discovered. They are now the world's most extensive diamond mines. [See Fig. 14–13.]

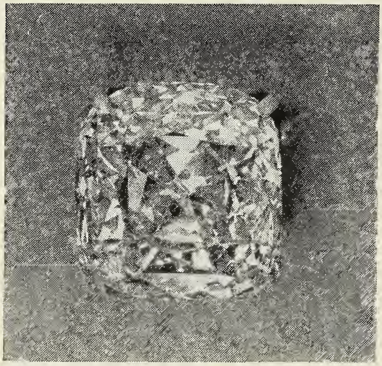


FIG. 14–13. The Tiffany diamond is pictured here actual size. It is an excellent example of a fine diamond. When we consider the beauty of precious stones, we can understand why some persons want to own them. (*Courtesy Tiffany and Co.*)

Chemists have succeeded in making both rubies and sapphires in the laboratory, and many attempts have been made to manufacture diamonds. A French chemist by the name of Moissan (mw*ä*·sän′) did succeed in making some, but they were so small that a microscope was needed in order to see them.

For those who cannot afford to buy emeralds or diamonds, the earth supplies stones of lesser value. Among the *semiprecious* stones are the opal, agate, carnelian, garnet, onyx (ŏn′ĭks), and the zircon (zûr′kŏn).

Some of the most valuable collections of jewels have belonged to the crowned heads of Europe, or have been in the possession of the famous cathedrals. The altar jewels in some of the cathedrals are noteworthy. Some very valuable gems are now in the possession of certain museums.

Fig. 14–14. There are many coral houses in Bermuda. They are often tinted with delicate colors. The roads, too, frequently are made of coral. (*Courtesy Bermuda News Bureau*)

206. What common rocks are particularly useful? (*a*) *Limestone.* This common rock, which is formed under water, is a stratified rock. Some of it had its origin in the shells of marine animals, such as clams, oysters, and coral. [See Fig. 14–14.] Much bedrock is composed of limestone, which is widely distributed in many states of the Union. It is used in the foundations of houses, and in some places the entire house is built of limestone. This rock may be crushed and used for making roads, either alone or with sand and cement. If limestone is heated strongly, it produces *quicklime*, from which masons make mortar and plaster. When limestone and clay are heated strongly, and the resulting mass is ground to a powder, cement is formed.

b) *Marble.* It seems reasonably certain that marble was formed from limestone which was at one time highly heated

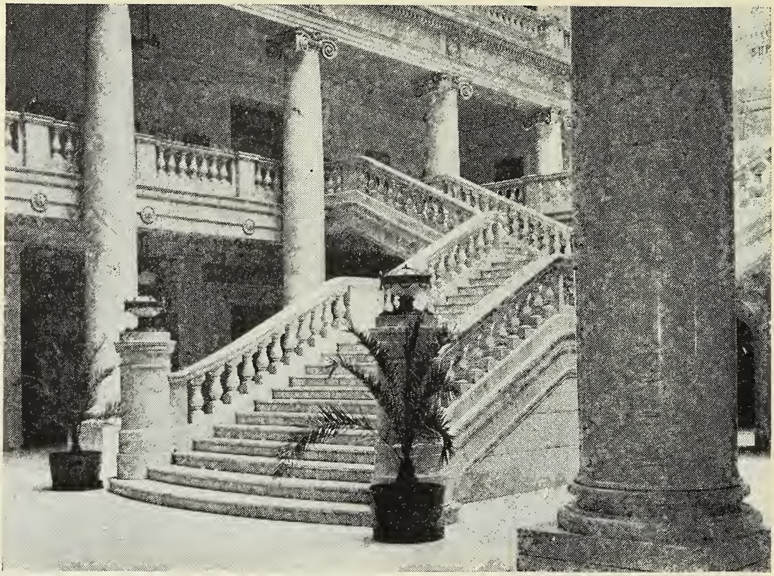


FIG. 14–15. The marble interior of the state capitol in Salt Lake City, Utah. (*Courtesy Salt Lake City Chamber of Commerce*)

under pressure in the earth's crust. It is fine grained, and it takes a beautiful polish. It is a splendid stone for decorating buildings, and is used especially for interiors. In the halls of the state capitol building in Salt Lake City, Utah, there are some excellent specimens of marble from the quarries of Georgia. [See Fig. 14–15.] The marble has been cut and polished to bring out a beautiful butterfly-shaped design. In the magnificent state capitol building at Baton Rouge, Louisiana, some thirty-two different kinds of marble are used in the different rooms. The Lincoln Memorial at Washington, D. C., is built entirely of marble. Some fine Italian marbles have been used for making statuary.

c) *Sandstone.* Probably this rock too was formed under water by the cementing together of particles of sand. It is used to some extent as a building stone. It is sometimes

sawed into flat slabs which make excellent sidewalks. If it is sawed into flat, circular disks, similar to giant pennies in shape, it can be used as grindstones.

d) *Granite.* Let us examine a piece of granite carefully. Without the aid of a microscope or a lens, we can see that it is made up of a mixture of at least three different kinds of rock, all firmly held together. The glassy-looking material is called *quartz.* It is also the hardest portion, being so hard that it will scratch glass. That portion which seems to split easily is called *mica* (mī′kȧ). It is used as the window in fuse plugs and in the front of coal ranges and hard-coal burners. It is an excellent insulator of electricity. In many cases it can be picked apart with the point of a knifeblade. The third portion, which is often pink in color, is called *feldspar.* It usually has rather smooth, shining surfaces. In some granites, *hornblende* (hôrn′blĕnd) which is seen in the form of black or greenish-black particles, is also present. Granite is a hard, durable rock which takes a beautiful polish. It makes excellent building stone but it is difficult to cut and polish.

e) *A few that are not so well known. Slate* is a rock which is believed to have been formed by heat and pressure. It has about the same composition as *shale,* which forms clay when it weathers. It may astonish you to learn that *asbestos,* (ăs·bĕs′tŏs) which is used to make fireproof suits, theater curtains that do not burn, and shingles for the roofs of houses, is a mineral which is taken from the earth. *Talc,* too, is a mineral. It is ground to a very soft powder and used for several purposes, among them being the making of talcum powder.

207. What mineral products do plants need? A good fertile soil always contains those elements which plants need as a food. But when a field has been farmed for many years, and the crops have been removed from the field, those ele-

ments which are needed for plant growth may be gradually removed from the soil. To keep his farm fertile, then, a farmer must add from time to time at least three elements which plants require: *nitrogen, potassium,* and *phosphorus.* All three of these elements, combined with other elements, occur in small quantities in many places, but there are not many places where large beds of them are found, of high enough purity so that it will pay to mine them.

a) *Nitrogen compounds.* There is plenty of nitrogen in the air, but for some strange reason, ordinary plants cannot take nitrogen directly from the air. They can take nitrogen from compounds of nitrogen which are dissolved in the soil water. Where can the farmer find such compounds? At one time no one cared very much about the exact location of the boundary lines that separate Peru, Bolivia, and Chile, largely because that region is a desert. But when rich beds of *nitrate*

FIG. 14–16. The men in this picture are using lime to enrich the soil. (*Courtesy Soil Conservation Service*)

were discovered there, all three countries wanted the territory. Chile is now in possession of those nitrate mines, from which much fertilizer food for plants has been obtained.

Of course farmers have known for a long time that plant and animal waste matter, or *refuse* (rĕf′ūs), contains nitrogen compounds. Hence farm manure, slaughterhouse refuse, fish scrap, straw, cornstalks, and sewage have been used on the fields as fertilizers. [See Fig. 14–16.]

Chemists have now learned how to take nitrogen out of the air and convert it into compounds which plants can use. Millions of tons of such fertilizer are made and used annually. Bacteria, too, can take nitrogen from the air and make it into compounds. Such bacteria grow in little knots, or nodules, upon the roots of such plants as alfalfa, clover, peas, and beans.

b) *Potassium compounds.* If one reads the history of Europe, he learns that Alsace-Lorraine (ăl·säs′lô·rān′) has at times belonged to France and at other times to Germany. One thing that makes this country particularly valuable is the fact that it contains extensive beds of potassium compounds (potash) hundreds of feet thick. Without potash, a green plant will not mature properly and produce seed. Prior to the World War of 1914, Germany shipped abroad many tons of potash. When the war broke out, the price of potash in the United States jumped from about $40 per ton to about $500 per ton. Nearly all the potash that had been imported came from Germany. At the close of the war, a part of this territory was given to France. If you consider the importance of such rich deposits of potash, you can understand why both Germany and France have coveted them.

c) *Phosphorus compounds.* We have learned how Germany held control of the potash mines. Of the compounds of phosphorus, the United States has a similar monopoly.

Mines which contain rich deposits of *phosphates*, which are phosphorus compounds, are found in Florida and some other southern states. The bones of animals contain phosphorus. The phosphate beds in Florida are believed to have been formed by the accumulation of bones from animals that lived in prehistoric times. Similar beds of phosphate rock are found in some western states, in the neighborhood of Yellowstone National Park. Phosphate rock is ground up and treated with an acid to make a plant fertilizer.

208. What are fossils? In a storm, an old tree was blown down in a forest. In a few years, the decaying trunk was covered with moss. In a few more years, nothing remained except a mound where the trunk had lain. The once-tall tree had been completely decomposed, and its material had gone back into the soil, where it would be used to nourish other growing plants.

The same kind of thing happens to an animal that dies in the woods, unless some other animal eats its body. The softer parts of the animal's body decay much faster than the wood of the tree. The hard bones may last for years, but they will decay too, in time, and go into the soil, helping to increase its fertility.

If such decay had always happened to plants and animals, we would have no way of knowing what sort of creatures lived on this earth before man came. In some cases, however, the bodies of plants and animals, after their death, fell into mud and water, or into beds of pitch, and they did not decay. In some cases they decayed slowly and mineral matter was deposited in the exact spot where they had been. We are almost correct in saying that they "turned to stone." The deposit of mineral matter completely filled the cavity formed by their decay. For that reason, such deposits look just like the original plants or animals. Of course such deposits last

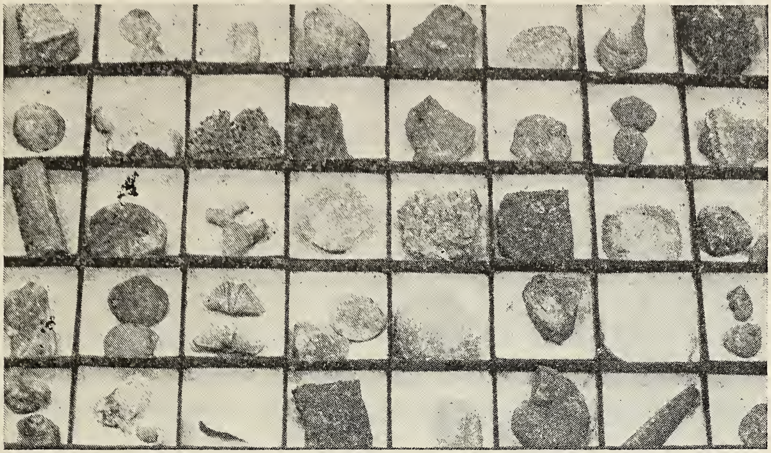


FIG. 14–17. A fossil collection is both interesting and instructive. Make your own collection, identify each stone, and label it carefully. (*Courtesy Ward's Natural Science Establishment*)

for ages. We call these remains and imprints *fossils*. [See Fig. 14–17.]

209. What story do fossils tell us? As more and more mud or sand was deposited over plant or animal fossils, they were buried deeper and deeper. Other creatures may have fallen into mud, sand, and water and their dead bodies may have been preserved in the same manner. The sediment in which they were buried may have hardened into rock under the influence of heat, pressure, and cementing materials. The fossils in the water, mud, and sand remained embedded in the rock like raisins in a cake. Many fossils of various kinds are found in sedimentary rock. Some fossils have been preserved in the tar beds of southern California.

The oldest layers of sedimentary rock are naturally the deepest. They are farthest from the surface of the earth. Scientists have examined the fossils in the oldest or deepest sedimentary rocks and compared them with those in succeeding rock layers. In that manner the scientists have

learned that the earliest plants and animals which inhabited the earth were very simple forms. Later more complex forms appeared. Many of these fossils have been dug out of the rock enclosing them. Any museum of natural history has specimens of fossils from which it is possible to study the order in which animals appeared upon our earth. The waters of prehistoric seas contained some animals no longer found upon the earth. There were strange *trilobites* (trī′lō-bīts), cup corals, and ancient forms of snails and clams.

Some of the fossil animals must have been terrifying when they were alive, because their size was enormous. Many of them were much different from those animals which live on the earth today, but they must have been the remote ancestors of the forms we see about us now, since the stream of life continues from parent to offspring. There were sharks large enough to have swallowed several men at one time. There were flying lizards of huge size, and land creatures with a huge fin extending all along their backs. Some of the animals were armored, and others had horns and spines. The dinosaurs and the *mastodons* (măs′tō·dŏnz) — gigantic elephantlike beasts — were much larger than any land animals we know today.

210. Why must we save our natural resources? In this chapter we have mentioned a few of the many treasures which a generous earth supplies for our use. At one time in the history of the United States, we used to say, "Uncle Sam is rich enough to give us all a farm." Because the United States has been so rich in forests, oil or petroleum, coal, iron, and many other valuable products, many of her citizens have grown extravagant. Unfortunately, many of them have not thought that it was important or necessary to practice thrift.

Sometimes the farmers grow more food in one year than we can eat. Then food products become cheap. Is that a

reason for growing less food? The farmers do not need to grow so much of one crop, but they may grow more different products to meet the demand for products which are now imported. Our chemists are now busy trying to make useful products out of farm wastes. Paper has been made from straw and from cornstalks. You may live to see the time when automobile engines will run not on gasoline but on alcohol made from farm wastes and mixed with gasoline.

No one can tell how long our supply of petroleum will last or how much new oil territory will be found. Certain fields have been reserved for use of our navy during wartime. It seems impossible that the supply can last forever, since it is being burned at the rate of billions of barrels every year. Can our generation afford to be so wasteful?

No one can tell how long our supply of coal will last, either, since we use it for fuel and for making steam to run our locomotives, and for our factories. We need to remember that man cannot make coal, and coal is not being formed by nature to any great extent at the present time.

We have been most wasteful of our forest supplies. It is true, of course, that trees may be planted and that areas may be reforested, but it takes from 40 to 100 years to grow a tree that is suitable for use as timber.

Do you think it is possible for anyone to make iron or copper? If not, what are we to do if we waste these metals by throwing away the scrap pieces? It is of the greatest importance that we learn to practice *conservation* of all our natural resources. It is bad enough to waste vegetables and other foodstuffs, but others *can* be grown again in a rather short time. An area can be reforested even though it takes a lifetime to do it. But what are our children and grandchildren to do if we waste the mineral products and other natural resources which no one knows how to replace?

Questions

1. Are there any good substitutes for iron and steel?

2. What is galvanized iron? For what purposes is it used?

3. We mine very little tin in the United States. We use about forty per cent of the world's supply. Why? Ask a chemist why he thinks we will probably be using much less tin in the United States in a few years than we do now.

4. The United States produces at least half of all the copper that is mined. Does that mean that we can afford to be wasteful of copper? Explain.

5. Which is superior for making monuments, marble or granite? Give a reason for your answer.

6. What do you think that we shall do when our iron mines fail?

7. Why has the discovery of mineral wealth been the cause of a number of boundary disputes among nations?

8. Make a list of all the uses you can think of for aluminum.

Some things for you to do

1. Make a collection of fossils, if you live where sedimentary rock is common. Chip away the surrounding rock carefully.

2. Visit a natural-history museum and study the fossil collection you find there.

3. Make a collection of minerals. You will need a great deal of help in identifying them. If possible, check your minerals with a labeled collection in some museum.

Plants Are Important to Us

In a recent summer, two children were lost for eleven days near South Colton, New York, in the Adirondack Mountains. They finally emerged from the woods, thin and worn, but able to walk. They had lived for a week and a half on raspberries and blueberries.

At any other time of the year than the fruiting season of these wild berries, the two children would have perished.

Through the ages, man has had the same problem. At certain seasons, he could find wild fruit or other food. At other times, he had to depend upon food stored from growing seasons, or he had to travel to lands where food was more plentiful.

Primitive man had to learn what plant products were valuable for food and what ones were harmful. In this unit you will read how, by means of cultivation, civilized man has learned to produce stronger plants of the kind that are valuable, and how he has learned to produce new kinds of plants.

You will read how man, as he found and used new plants, discovered the uses of wood, fibers, dyes, spices, sap, medicines, and oils. You will understand that man has come to depend on plants for hundreds of new uses, and that civilization today would be impossible without plants.

THINK ABOUT THESE!

1. What is a seed? Do all plants have seeds?
2. How do bees help to make seeds?
3. What is one kind of fruit that has a waterproof covering?
4. Do you know fruits that scatter seeds by a kind of explosion?

WORDS FOR THIS CHAPTER

Pollen. Small grains, or cells, which are formed on the stamens of a flower. They usually appear as a brown or yellow powder.

Stamens (stā′mĕnz). Threadlike parts of a flower on which pollen is formed.

Pistil. The tall, central part of a flower, which includes the ovules.

Cross-pollination. Depositing pollen from one flower upon the pistil of another flower of the same kind.

Ovule (ō′vūl). The beginning of a seed before fertilization; an unripe, or undeveloped, seed.

Ovary (ō′vȧ·rĭ). In a plant, the part at the base of the pistil in which the seeds grow.

Fruit. The ripened ovary, together with any other closely connected parts.

Colony. A group of many individuals, usually of the same kind, living together.

Seedling. A young plant just after sprouting from the seed.

Spore. A small cell by means of which certain flowerless plants – molds, for instance – reproduce. In function a spore corresponds to a seed.

CHAPTER 15 ________________ *UNIT 7*

What Makes Plants Grow?

211. **Why are there flowers on plants?** As you have already learned, most plants bear flowers. Almost everyone likes flowers. There are certain persons, sometimes whole families, who appreciate flowers so much that they will travel long distances just to see a display of beautiful cherry blossoms or chrysanthemums. Yet, although flowers are among the most beautiful things in the world, we must remember that the plants which produce flowers cannot think and therefore cannot appreciate such beauty. What is the importance of flowers to plants?

The lovely colored part of flowers, called the *petals,* is really a sign or advertisement to bees and other insects. Of course you are wondering what the petals advertise. It is a remarkable story.

212. **How does the bee help to make seeds?** Inside each flower is a sweet liquid called *nectar,* which is usually held in a little pocket. Insects like this nectar, just as boys and girls

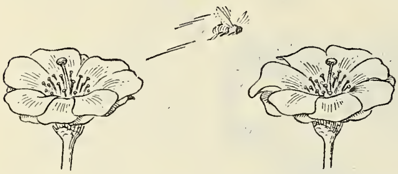


FIG. 15–1. As the bee goes from flower to flower, she distributes pollen.

like candy and ice cream. When the insect, attracted by the showy petals, comes to the flower to get some nectar, the hairy body of the insect is dusted with some of the yellowish or brownish powder found in most flowers. This powder is called *pollen.* Pollen consists of tiny grains. It grows on the ends of threadlike parts called *stamens.* [See Figs. 15–1 and 15–2.]

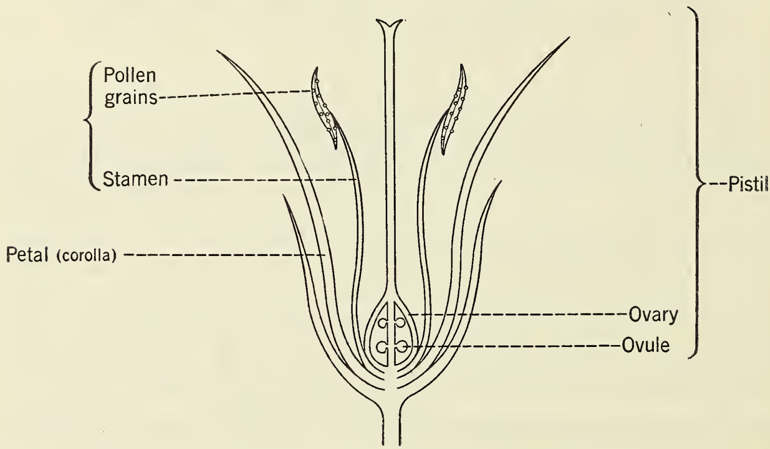
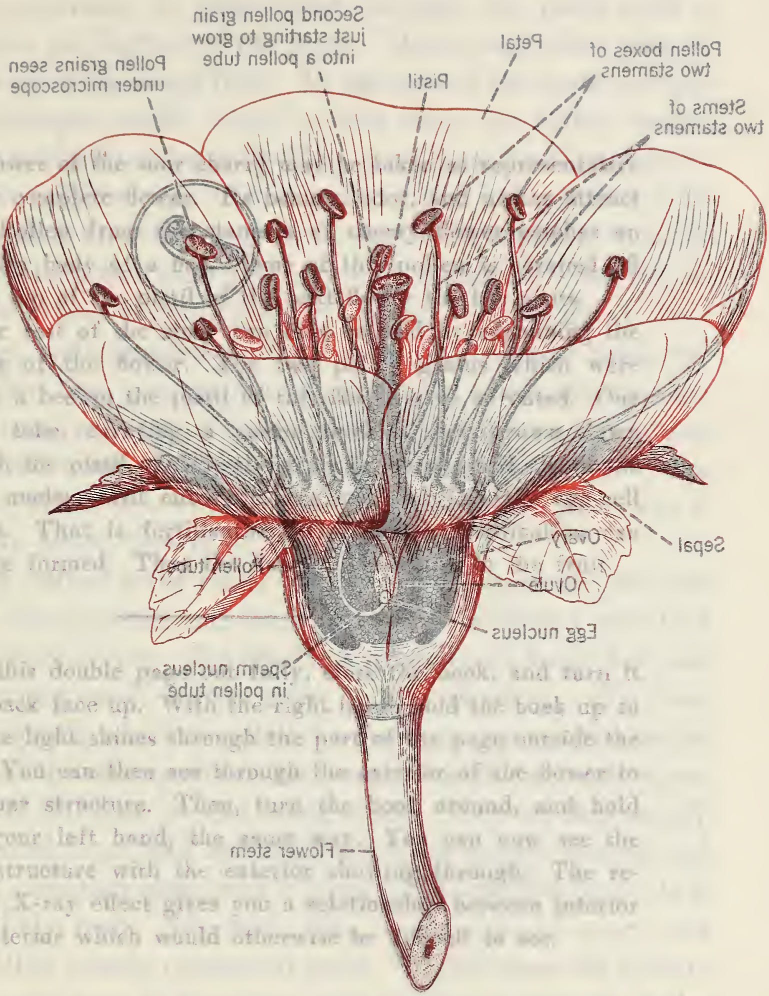


FIG. 15–2. By using this diagram and the accompanying text, can you explain how cross-pollination takes place?

When the bee goes into the next flower for more nectar, some of the pollen is brushed off on the top of the tall, central part of the flower, called the *pistil.* This top is sticky. Some of the pollen stays there and starts to grow. From a cell in each sprouting pollen grain, a delicate pollen tube emerges.



Hold up to light for X-ray effect. Then turn page for explanation and detail

The flower of the sour cherry may be taken as representative of any complete flower. Its beauty, odor, and nectar attract bees. Pollen from the stamens of cherry flower catches on the hairy body of a bee. Some of this pollen is scraped off on the top of the pistil of the next flower the bee visits.

The rest of the story can best be told by examining the interior of the flower. The two pollen grains which were left by a bee on the pistil of this flower have sprouted. One pollen tube, carrying a sperm nucleus, has grown down through the pistil. Inside the ovule is the egg cell. Soon the sperm nucleus will enter the egg cell and join the egg-cell nucleus. That is fertilization. Only after fertilization can fruit be formed. Thus the flower is essential to the fruit.

Open this double page out fully, close the book, and turn it over, back face up. With the right hand, hold the book up so that the light shines through the part of the page outside the book. You can then see through the exterior of the flower to the inner structure. Then, turn the book around, and hold it in your left hand, the same way. You can now see the inner structure with the exterior showing through. The resulting X-ray effect gives you a relationship between interior and exterior which would otherwise be difficult to see.

After this process of *cross-pollination* has taken place, this tube continues to grow down through the pistil until it reaches the bottom of the pistil. Many such tubes may be growing at the same time. In the base of the pistil are tiny undeveloped seeds, which at this stage are called *ovules.* Each ovule, in order to develop, must have a nucleus from a pollen cell, by way of the pollen tube. If a pollen tube does reach an ovule, it gives the ovule the nucleus; then the rest of the pollen tube dies. Its work is finished. But the little ovule now starts to grow in earnest. Soon it gets to be a plump, well-rounded seed. If you open this new seed, you will find that it is really a young plant, which has become thickened with stored food. When it becomes much larger, two seed coats, or skins, form around it. Now it is a true seed. When it is entirely ripe, it is no longer green but is usually black, brown, or yellowish.

213. What is the fruit? While this is happening, the colored, showy petals and the stamens have withered, now that their work is over. The pistil has grown much larger because the young seeds within grow as they develop. The base of the pistil, which is called the *ovary,* is a part often larger than all the other parts of the flower. Inside the thick, green walls of this base are the young seeds. They are thus snugly protected from cold and rain, and from hungry insects and birds. Another name now is given to this swollen base. It is called the *fruit.* The fruit, then, is the ripened ovary and any other closely connected parts. At this time the fruit is green and sour to the taste. But under the warmth of the sun, the fruit ripens into the shape and color and flavor of its kind. [See Fig. 15–3.]

The fruit and its seeds mature only where there once was a flower. Since seeds are the usual means of getting a new plant, we can see how important flowers are to plants. Nor

FIG. 15–3. The blossoms in this picture are those found on a cherry tree before the cherries appear. You may have seen flowering fruit trees of one kind or another growing near your home. Can you describe the process that changes these flowers into the fruit you eat? (*Courtesy Caterpillar Tractor Co.*)

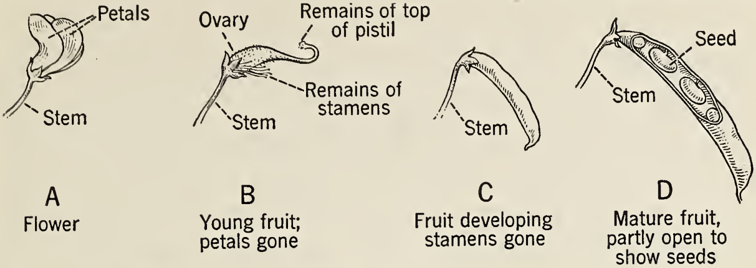
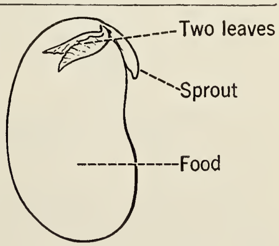


FIG. 15–4. This diagram shows the development of the bean from the flower to the fruit. The bean is a common fruit, and perhaps you have seen it growing. Can you explain in your own words this developing process?

should we forget those pollen grains, for without them no seed can come. [See Fig. 15–4.]

214. What is inside a seed? If you open a fruit, you will probably find in it one or more rounded objects. From the preceding paragraph, you recognize them as seeds. Have you ever opened a seed and looked to see the young plant we have just talked about? Suppose that we do that together, examining a soaked bean seed. First we shall slit the skin with a pin or a knife. The rounded mass within easily separates into two parts, each looking like the half of a peanut. Look closely at the little part near one end. It has two leaves like crossed hands, and a small pointed sprout. This part is the young plant. The two rounded parts supporting it are full of food for the use of the little plant when it starts to grow. [See Fig. 15–5.]

FIG. 15–5. Internal structure of the bean seed. The two little leaves (sometimes called plumules at this stage of development) will become a part of the plant aboveground. The sprout will develop into stem and roots. (The other half of the seed containing food, and also the seed coats, has been removed.)



215. How are seeds scattered? Some seeds, like those of the dandelion or the milkweed, have hairs attached to them, and can easily be carried long distances by the wind. Thus they start *colonies* of plants in new places. Other fruits have little hooks on them. These hooks catch in the hair of passing animals or on the clothing of people, and are thus carried far away. Wherever the seeds drop out, new plants come up, if conditions are favorable. Thus such plants can spread more widely. It is true that those plants that are the commonest in different parts of the earth, usually have good means of scattering their seeds. Examples of seeds or fruits distributed by animals are the well-known burs such as burdock and cocklebur, and also such forms as beggar's tick. There are many more such "hitchhikers." [See Fig. 15–6.]

Some fruits, like the coconut, have a thick, waterproof covering and are carried to new lands by the winds and ocean

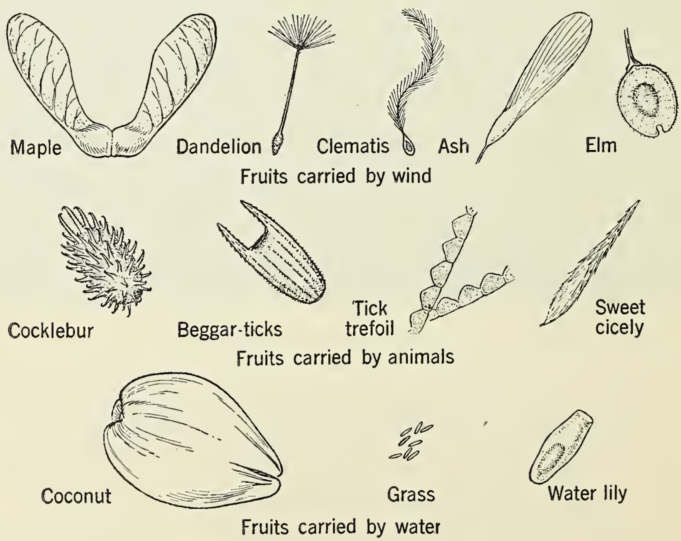


FIG. 15–6. Curious structures on certain fruits permit the seeds to be carried far away from the parent plant.

currents while floating in the water. The seeds of many grasses and sedges – the tough grass that grows at the edge of lakes and streams – are light and also float away on streams.

A few fruits have the curious method of scattering their seeds by a sort of explosion. The witch hazel shoots out its seeds from the thick-walled fruit almost as from a little gun, and with a sharp, popping sound. A plant which grows in moist places and which has orange flowers is called *jewel-weed.* It has little green pods; if these are touched after they have ripened, they suddenly split and curl, throwing the seeds in all directions. [See Fig. 15–7.]

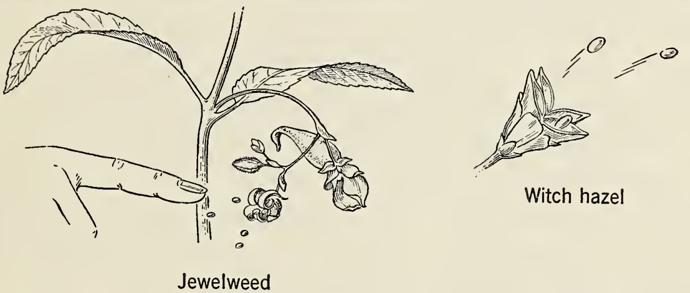


Fig. 15–7. How do the jewelweed and witch hazel scatter their seeds? Are they like most other plants in this respect?

Many birds eat wild cherries, each of which contains a hard seed. The seeds are not affected by the birds' digestive juices, and many of the seeds, after passing through the bodies of the birds, fall to the ground along fences bordering country roads, where the birds have roosted. These seeds sink into the earth and, under favorable conditions, grow into wild cherry trees.

216. How does the young plant in a seed get out of the seed coats? Let us see how the little plant in a seed grows above the ground and becomes a green plant.

The best way of finding out such secrets is to watch seeds

change into *seedlings* and then grow up into young plants. Get half a dozen kinds of seeds, perhaps seeds of the bean, corn, pea, squash, radish, and sunflower. Let the seeds soak in water overnight. The next day, put some loose cotton batting at the bottom of a tumbler, then roll up a white blotter and slip it around inside the glass so that it touches the glass from top to bottom. Pour in enough water to wet the cotton and the blotting paper. Then take the soaked seeds, which are now larger than they were when dry. Push them down between the blotting paper and the glass, a little distance apart. Put the tumbler of seeds away where it will be safe. Be sure to wet the cotton every day. The next day, and each of the following days for two weeks, be sure to look at your tumbler garden. Notice every change that takes place. Some of the seeds will sprout more quickly than do the others. The little white point that slowly pushes its way out of the dark seeds, is coming into a new world. It is doing things for the first time. Do you wonder how it can do them without being taught? Perhaps it is obeying laws that govern the actions of living things. [Fig. 15–8.]

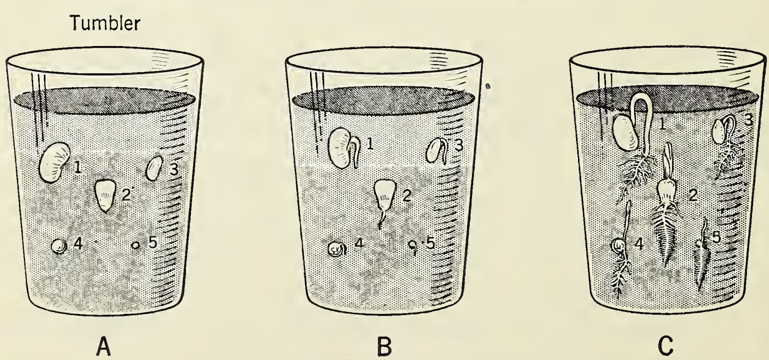


Fig. 15–8. A tumbler garden is excellent for observing growing seeds. *A*, *B*, and *C* are three stages in a few days' growth of five seeds: (1) bean, (2) corn, (3) squash, (4) pea, and (5) radish.

217. What is a young seedling like? Can you tell which part of the seedling is going to be the stem? Watch for the first roots. In what direction does the stem grow? In what direction does the root grow? Do all the roots grow in the same direction? Notice the first leaves and the first bit of green color in any part of the seedlings. Plants, like animals, must have food. Now you can realize better why some of the seeds, like peas, beans, and corn, are so plump. They are filled with food for the seedling, or growing plant, which is not yet ready to begin manufacturing its own food. This food is a sort of lunch, provided by nature, for the earliest period in the life of the plant. Human beings get nourishment by eating peas, beans, or other seeds: that is proof that there was a food supply packed in the seeds.

Of course the supply of food in the seeds will be used up after a little while. Then the tumbler seedlings are sure to die unless they can be planted in soil. If the plant can be kept growing, parts of the stem and leaves will become green. That is a sign that the plant can now make its own food from the water it takes in from the soil through the roots, and from the carbon dioxide which the leaves take in from the air. Think how wonderful it is that even such common plants as grass and trees can, in their green parts, make food out of lifeless materials. Animals, which cannot make food in this way, must eat plants, or other animals that get their food from plants and turn it into animal tissue, or substance.

218. How can new plants come into existence without flowers? (*a*) *By cuttings.* Those of you who live in the country have surely seen someone in the spring cutting potatoes into pieces to be planted in the ground for a new crop. There is a little trick about doing this. One must be careful to cut so as to leave one or two of the small buds, or sprouts, on each piece of potato. Each of these buds is called an *eye*.

In the soft, moist earth, from each of these eyes a sprout will start to grow, nourished by the food in the piece of potato. From such a small beginning, if all goes well, a big plant will develop. It is true that the potato plant has flowers and thus produces seeds. However, it takes very much longer to grow potato plants from their tiny seeds. Most farmers plant parts of potatoes containing the eyes, which are actually underground stems. [See Fig. 15–9.]

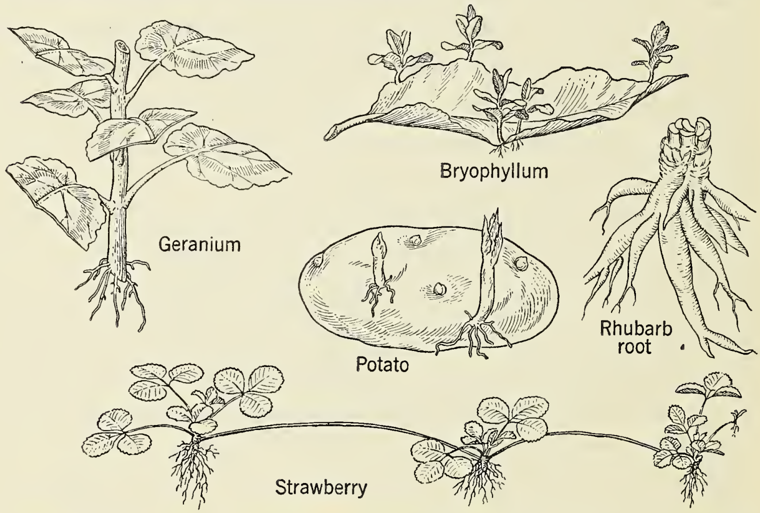


Fig. 15–9. Can you tell by what method each of the plants in this diagram reproduces?

b) *By slips.* One of the most beautiful of our flowering plants is the geranium. This plant, like the potato, produces small seeds, but flower-growers do not plant these seeds. Instead, a branch of the parent geranium plant is cut off and put into water or moist sand. In two or three weeks small roots will begin to show on the lower end of the branch. If this geranium branch, now called a *slip,* is planted, under favorable conditions it will grow into a plant like the parent.

A huge willow tree now growing in the barnyard of a farm in Pennsylvania has a strange history. At the end of the War between the States, a wounded soldier on his way home made a cane from a stick cut from a willow branch. He used the cane to help him walk. When he had reached his home, and had no more need for the cane, he stuck it into the moist earth near his barn. It grew roots and leaves and finally became a tree like the parent willow from which it had been cut. Branches from rose bushes and from *privet* (prĭv′ĕt) will usually grow roots, just as the willow stick did, and develop into normal plants if they are put into moist earth.

c) *By spores.* In certain plants like mushrooms and ferns, neither of which ever produces flowers, there are developed tiny *spores,* which are actually very small cells with thick walls. When these spores are dropped, they may grow into new plants. The black or bluish dust seen when bread or some other substance becomes moldy, consists of thousands or millions of the spores of mold.

d) *By leaves.* One of the strangest ways of developing a new plant without seeds is found in the case of the *bryophyllum* (brī′ô·fĭl′ŭm). If a leaf of this common plant be left for some time on moist soil, little bryophyllum sprouts will begin to form along the edges of the leaf. When they have used up the nourishment in that leaf, they are usually ready to shift for themselves and make their own food like any green plant.

e) *By roots.* There are many cases where a new plant will develop if the root, or even a portion of the root, be planted. The rhubarb, dahlia, phlox, raspberry, and many other plants, will produce new plants from a portion of their roots.

f) *By bulbs.* Another example of a plant developing without seed is the *bulb.* This is seen in the gladiolus, hyacinth, tulip, onion, and many other plants. A bulb is a sort of stem made up of layers of skin, covering leaf buds and flower buds.

When it is planted, it starts to grow in the spring, by sending down roots and sending up leaves and flowers. After it has flowered, it begins to store up food and make a new bulb, sometimes more than one, for next year's growth.

g) *By runners.* Some plants, such as strawberries, raspberries, certain grasses, and some of our weeds, have an interesting method of forming new plants. A stem, or *runner*, is produced, which grows along the ground, extending away from the parent plant. Where this stem comes into contact with the moist ground, or becomes covered with earth, a new plant starts to grow. The roots are sent down, and the leaves grow upward. Eventually the runner is broken, and then the new plant is entirely independent.

Questions

1. There are two kinds of flowers on some plants; one has stamens but no pistil; the other has a pistil but no stamens. If you were buying strawberry plants in order to have strawberry fruit, which kind of flowering plant would you ask for? Explain.
2. Where do you think the nectar which the bee finds in flowers comes from?
3. How would you define a seed?
4. What part of the flower might well be called an advertisement? What is the flower advertising? To whom is it advertising?
5. Why is it of advantage to plants that fruit is usually sour when unripe?
6. Can you name several examples, not mentioned in this chapter, of seeds fitted by structure to be carried away by the wind?
7. Can you name several examples, not mentioned in this chapter, of seeds fitted by structure to be carried away by animals? Which were the most difficult to remove from your clothing?
8. Can you account for the presence of many shrubs, including wild cherry, along most of the roadsides in the country?

9. Can you name plants, other than those mentioned in this chapter, that can reproduce without flowers?

10. Why do men develop certain new plants without planting their seeds?

11. What is the difference between a spore and a seed? Between a seed and a fruit?

12. Why is it important to have bees in an orchard?

13. What parts of a flower are necessary for the making of seeds?

14. Which do you think can live longer, a seed or a spore? Explain.

Some things for you to do

1. Make a collection of fruits and seeds that are distributed by hooks or spines. Collect as many kinds as you can, and draw each one as you see it under the magnifying glass.

2. See how far the wind will carry a milkweed seed with its parachute of silken hairs. Measure the distance, if you can.

3. Make a spore print of a mushroom. Cut off the cap, or head, and place it, with the gills down, on a piece of paper. Cover it with a glass or a bowl and leave it overnight. By the next morning the spores that have dropped out of the mushroom will have formed a beautiful pattern on the paper. If the spores are light colored, they will show better on dark paper. This spore print can be preserved by spraying it with lacquer or thin shellac. Your art teacher can help you do this.

4. Try to grow some unusual plants from seed. Plant the seeds of oranges, lemons, and grapefruit; try also the seeds of a maple tree and of an oak tree (acorns).

5. In separate jars of water, grow plants from an alligator pear, a carrot, a beet, a parsnip, and pieces of a sweet potato. The alligator pear makes a beautiful plant, but it takes a long time to sprout.

6. Try to raise a plant from a slip of a geranium, coleus, or begonia plant.

THINK ABOUT THESE!

1. What kind of tree or other plant do you think is the most valuable to man?

2. Throughout the world, what natural plant food is most widely used by man?

3. Can you explain what would happen to our world if all the plants were suddenly to die out?

4. Do you know any kind of microscopic plants that cause diseases in animals and in plants?

WORDS FOR THIS CHAPTER

Deciduous (dē̇·sĭd′ū̇·ŭs). Having leaves that fall at the approach of winter.

Aromatic (ăr′ō̇·măt′ĭk). Having a pleasant odor.

Mulch (mŭlch). Material, such as straw, used as a covering for plants in the winter.

Fungus (fŭng′gŭs). A flowerless plant, such as the mushroom.

Ash. Mineral matter that resists burning.

Fermentation. A chemical change produced by yeast or some similar substance called a ferment.

Dehydrated (dē·hī′drāt·ĕd). Freed of all water, as dried fruit, for example.

Preservative. An agent that prevents decay.

CHAPTER 16 ______________ UNIT 7

How Do We Use Plants?

219. How does man use plants? To discuss all the ways in which man uses plants would require a large volume. In a short chapter, only a few of the many uses of plants can be mentioned. You have already learned that green plants take in carbon dioxide which animals have breathed into the air. You know that in the process of foodmaking, the green plants give back to the air the life-sustaining oxygen which all animals require in the air they breathe. We know, too, that animals are dependent upon green plants for food, because animals cannot make starch, sugar, or protein from the raw materials of the air and soil. Yeast, molds, and many bacteria, though not green plants, are useful to man. There are many other ways in which plants are of value, both to savages and to civilized men. Suppose that you make a list of as many of these ways as you can, before starting this chapter; then see how many of these uses of plants are discussed here.

220. How old are the forests of the earth? Before the dawn of the Christian era, some of the Sequoia, or redwood trees, in California were already giants. When Columbus discovered America, they had for centuries been towering over the wigwams of the Indians. But although they are larger and more awe-inspiring than the white pines, the hemlocks and the Douglas firs, they are not so useful. In the eastern part of the United States there are *evergreen* forests of spruce, hemlock, pine and balsam, and the *deciduous* forests, which include the magnificent oaks, elms, maples, beeches, and birches. Farther south the yellow pines grow in abundance.

We have seen how forests aid in preventing destructive floods. They afford shelter for game and for fur-bearing ani-

FIG. 16–1. The two lumbermen are starting to fell this sturdy pine tree. First they cut a deep notch on one side. Then, on the opposite side of the tree, using a huge saw, they slowly saw through the trunk. The tree cracks at the notch, and crashes to the ground. In what direction will this tree fall? (*Photo by U. S. Forest Service*)

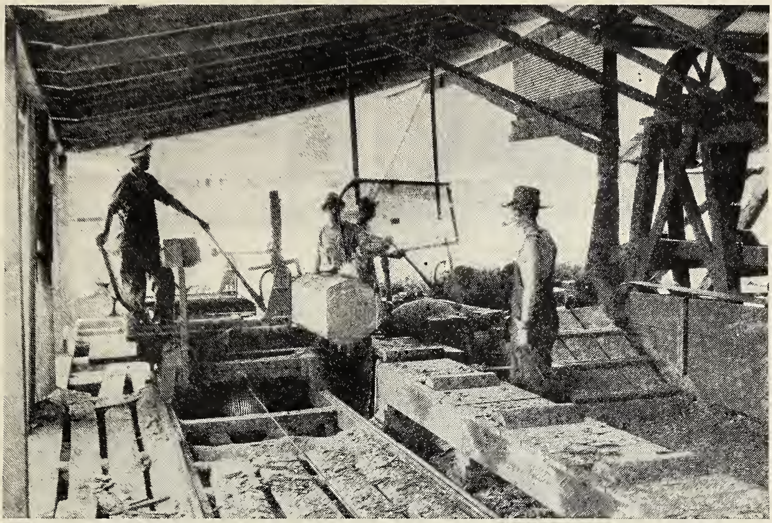


FIG. 16–2. Logs are converted into lumber in the sawmill. Circular saws revolving at high speeds cut the logs into boards and lumber of various dimensions. The huge piles of sawdust always seen around sawmills show that there is much waste. How could such waste be avoided? (*Photo by U. S. Forest Service*)

mals. They break the force of destructive winds which sweep over the land. They provide man with places for rest and for recreation. Trees help to purify the air. Trees also cool the atmosphere because of their shade and because of the evaporation of moisture from their leaves and from the ground under the trees. You can probably think of many more examples of their usefulness.

221. What is a log, and what comes from it? One of the chief benefits of forests is to furnish wood for innumerable uses. [See Fig. 16–1.] Tall straight trees are cut down, their branches chopped off, and the trunks sawed into lengths of from twelve to eighteen feet. Each length is called a log. These logs are then rolled or hauled to some stream. In the north, lumbering is usually carried on in the winter.

When the snow and ice melt in the spring, and the stream becomes swollen, the logs are floated down to the sawmills. Here the logs are sawed into boards and lumber of desired width and thickness. In some localities the logs are piled on flatcars or trucks and are hauled to the sawmill.

Lumber is used in a great variety of ways. [See Fig. 16–2.] The framework of many of the homes in this country is made of lumber. Pine, fir, hemlock, oak, chestnut, maple, and the wood from the tulip tree are all extensively used in home construction. For our furniture, birch, beech, walnut, maple, elm, sycamore, oak, and mahogany find many uses. Our baseball bats and oars and the ribs of rowboats may be made of ash wood. The chief use of a particular wood, as of a particular metal, depends upon some unusual property of the wood itself. Oak, which is strong, has been for centuries the favorite wood of shipbuilders and of barrelmakers. Hickory, which is tough, is suitable for the handles of axes, hammers, golf clubs, wagon wheels, and other similar products. *Aromatic* cedar, which is offensive to clothes moths, is useful for making chests and for lining closets. Probably you can name ten other things that are made of wood. If a complete list of all wooden objects and products were made, it would be very long.

222. How is paper made? Do you know of what material the page you are reading is composed? We call it *paper*. Perhaps you know that it consists mostly of wood. Spruce is especially desirable for making paper, although other woods, such as poplar, may be used instead. Recently, attempts have been made to use waste cornstalks, cotton stalks, and straw of different kinds for making paper. Some attempts have been fairly successful, and these products will no doubt be used more extensively as forests disappear. Recently a method has been found of getting rid of the gummy

pitch from southern pine or from slash pine — the pine that grows in slashes, or marshes. This wood can then be used for making paper. This will mean a great deal to the southern states where this pine grows extensively.

In making paper from spruce, the logs are sawed into short blocks. [See Fig. 16–3.] In the paper mill these blocks are first chipped by being pushed against revolving stones. The pieces thus produced are treated with some chemical. This dissolves the gummy substances in the wood and leaves nearly pure *cellulose* (sěl′ū·lōs) which is the woody fiber that forms the groundwork of plant tissues. If white paper is desired, some bleaching agent is used. The mass is converted into pulp by being run through knives placed on rollers in a beating machine. From the beaters, the pulp, which is sus-

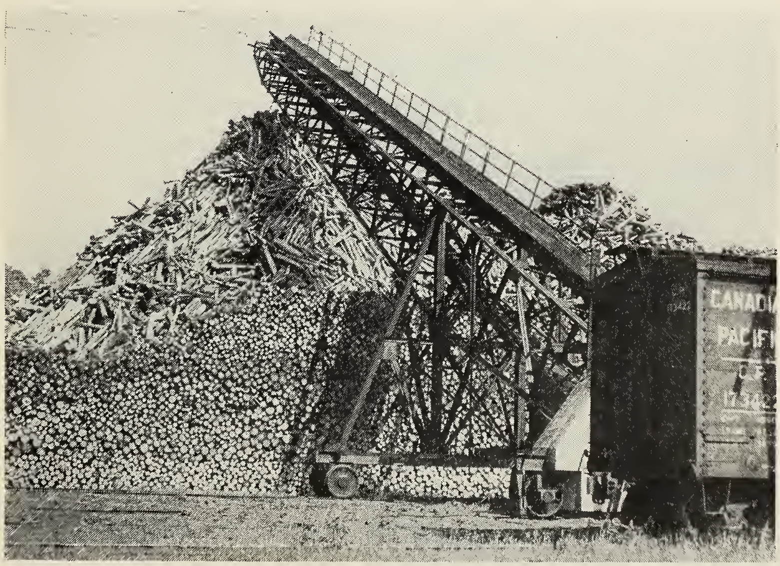


Fig. 16–3. Wood fiber is used more than any other material for making paper. Notice that the bark has been taken from these logs. Pulpwood, as such wood is called, consists of pieces of logs only about four feet long. (*Photo by U. S. Forest Service*)

pended in water, is run upon screens to form a mat of fibers. This layer of fibers passes through rollers which squeeze it and then press it dry and thin enough to form paper.

This paper may become writing paper, with a hard and smooth surface, by the addition of cloth or of a material called *sizing* (sīz′ĭng). If we consider the amount of paper needed to print the Sunday edition of one newspaper such as the *New York Times* – some 750 tons – we can understand why it is necessary for chemists to try to find some material besides wood pulp for making paper.

223. What are some other forest products? The hard-maple trees scattered throughout the northeastern part of the United States supply thousands of pounds of maple sirup and maple sugar each spring. From each tree that is tapped, a sweetish watery sap is collected and boiled down over a fire until it becomes a thick sirup. The *cinchona* (sĭn·kō′nȧ) trees of the Peruvian forests supply us with *quinine* (kwī′-nīn). In Africa, Mexico, South America, and the East Indies

FIG. 16–4. The man in this picture is collecting the latex from a rubber tree. Can you explain how the rubber is obtained from this whitish mass? For what reasons is rubber kept elastic? How is it vulcanized? How many products that are made of rubber can you name? (*Courtesy Goodyear Rubber Co.*)

the rubber trees grow. From a cut in the bark of the trees the whitish sap, called *latex* (lā′tĕks), flows out and is collected in buckets. [See Fig. 16–4.] The rubber is separated from this latex, either by means of heat or by the use of an acid. It is then washed and milled to make it elastic so that it can be mixed with other substances to make tires or other rubber articles. Crude rubber is *vulcanized,* or hardened, by heating it with a proper amount of sulfur.

Turpentine, which comes mostly from the long-leaved pine of the southern states, is obtained by notching these trees and collecting the material which seeps through the cut surfaces. Turpentine, pitch, and rosin are extracted from this material. Turpentine is a good *solvent,* and it is used as a thinner of paints, especially for use inside of buildings.

Camphor gum is obtained from the camphor tree. It is made from the twigs and from the leaves. Korea and Japan for years nearly controlled the world's supply of camphor, but trees have been planted in other places and seem to thrive well. Florida now has camphor groves and plants, or *refineries,* where the camphor is extracted. Very recently camphor began to be made artificially in chemical laboratories.

The dyewoods of South America, such as logwood, from which coloring matter can be extracted, find some use, especially by the South American Indians.

From other trees are obtained bay rum, cinnamon, cocaine, allspice, nutmeg, cloves, and many other products prized by man. The bark of the cork oak supplies us with cork.

224. Why are cereals important? The so-called cereals include such plants as wheat, oats, barley, rye, corn, and rice. These grains all contain starch, protein, and oils which are made by the growing leaves and stored in these seeds to supply nourishment for the next generation of plants. Both man and the lower animals use these products extensively for

Fig. 16–5. How many uses can you name for the wheat that the men in this picture are threshing? (*Courtesy International Harvester Co.*)

food, but man always saves good seed for planting. The farmer depends upon corn and barley to fatten his hogs for market. He feeds his horses oats. He knows that his cows will give more milk and richer milk, if ground corn, oats, or barley is added to their foods. Among the Mongolian races, rice is a staple article of diet. The citizens of the United States and Europe are so dependent upon wheat and rye for flour that the slogan " Wheat will win the war " was common talk in 1917–1918. [See Fig. 16–5.]

The straw of these grains is useful too as a cheap fodder, or food, for farm animals. It serves as bedding for horses, as *mulch* for plants in the fall; and sometimes it is plowed under the soil as fertilizer. Fiber board, now used so much as a heat insulator, can be made from straw and cornstalks. Cooking oils, also, are obtained from corn.

225. What are the fiber-producing plants? Much of our clothing comes from the fibers of certain plants. Such plants as *cotton, flax, hemp, sisal* (sĭs'ăl) and *jute* are fiber-producing plants. Their fibers are long enough and strong enough to be spun into threads, cords, or twine, and then woven into cloth. After the petals of the cotton flower fall and the seeds of the plant ripen, the outer coating of each seed becomes covered with white fibers. These fibers, when separated from the seeds, are used for making cotton thread and cotton cloth. Cottonseed oil, which is used in salad dressing, is squeezed out from the seeds. What is left is cottonseed cake or meal, which makes an excellent food for cattle. In commercial importance no other fiber plant is nearly so valuable

FIG. 16–6. The man with the sack over his shoulder has just come in from picking cotton in the fields. He is waiting to have the sack weighed, because he is paid according to the weight of the cotton he has picked. The pile of cotton at the left of the picture is ready to be carried away by the truck. (*Courtesy Cotton Textile Institute*)

FIG. 16–7. This picture of sisal plants was taken on the island of Haiti, where it is grown. The outside leaves of the plants are cut off each year for four or five years. Then the center stalk goes to seed (see the last plant on the left). The plant is then useless. From sisal are made cheap grades of string and rope. (*Underwood and Underwood*)

as cotton. It ranks with corn, wheat, and other grains. [See Fig. 16–6.]

Second in importance to cotton as a fiber plant is flax, from which linen is made. By a process known as retting, in which bacteria play a prominent part, the fibers are separated from the rest of the plant. They are then bleached, spun, and woven into linen cloth. From the seed of flax, linseed oil is obtained. Linseed oil is commonly used in mixing paints. Ramie or "China grass," is similar to linen in its properties. Hemp, from the Philippine Islands, produces a very strong fiber that is used for cordage and for ropes. Sisal is used for making strong twine. [See Fig. 16–7.] Jute, cultivated in India, has a coarse fiber which is used for making burlap bags and the backs of carpets.

226. What are some other useful plants? In addition to the plants already studied, there are many others that are of commercial or food value. The number of garden vegeta-

bles is large. Many trees produce nuts. Nearly every farmer has some fruit trees, and orchard crops are an important source of revenue. There are many grasses that are good for pasturage and for fodder for animals. Many plants are cultivated for the beauty of their flowers or their foliage. The lichens, a combination of a *fungus* and a plant with green cells, are the main food supply for the reindeer of the frozen northlands. Seaweeds are raked ashore, collected into a pile, then burned, and iodine is extracted from their *ash*. From the same source, men obtain potash which is a valuable plant fertilizer. Some of our most important medicines are extracted from the roots, stems, leaves, or seeds of plants.

Nature is indeed generous, but there is not an unlimited supply of these valuable wild trees and plants, and conservation of many plants, chiefly trees, is important.

227. How shall we conserve our forests? Conservation of our forests is important because it takes from forty to a hundred years to produce forest trees suitable for lumbering. Many of our states are now paying particular attention to such conservation. The various steps include: (*a*) care in cutting timber to prevent injury to standing timber, leaving trees standing at intervals to insure the reseeding of the area, and removal of rubbish left from trimming the timber; (*b*) prevention of forest fires by cutting gaps to prevent the spread of fires; by burning, under direction, the branches trimmed from the trunks of trees that are cut by forest rangers; and by educating campers in the care of campfires, and the disposal of cigar and cigarette stubs; (*c*) reforestation, which means the planting of two or three trees for every one that is cut, or the planting of trees under government supervision in areas that have been deforested. Much of this is being done in regions that are so hilly or so rocky that the land areas are not suitable for agriculture. In many states,

FIG. 16–8. A four-year-old pine tree, grown from seed in a state tree nursery, is being planted. A hole deep enough to hold the long roots without bending them is first dug. Then the little tree is planted at the depth at which it was growing in the nursery. Finally the soil is firmly pressed down around the roots to hold them in place and to keep too much moisture from escaping from around the roots. (*U. S. Forest Service Photo*)

young trees suitable for such planting can be purchased, at very small cost, from the State Conservation Commission. [See Fig. 16–8.]

228. What fuels are obtained from plants? Whenever you have built a fire or have seen a fire burning, the probabilities are that the fuel came from wood, from coal, or from petroleum products. That is, the fuel came either directly from plants or from material derived from plants. As you have learned, coal is nothing more than parts of plants that lived millions of years ago. Kerosene, fuel oil, gasoline, illuminating gas, tar, and similar products are derived from petroleum or from coal.

229. **What are weeds?** Plants do not always aid us; there are many plants which are injurious to man; some more so and some less. For instance, up to the present time, no one has found the purslane, the plantain, the knotweed, the ragweed, the thistle, the chickweed, the dock, or the dandelion worthy of cultivation. Since such plants are relatively useless to man, and interfere with man's crops, they are called weeds. Thus a weed might be referred to as "a plant out of place." Weeds produce many seeds, a great many of which escape being eaten by birds. Being very hardy plants, they grow in such great profusion that they rob other plants of the air, sunshine, and soil space needed for successful development. Perhaps their greatest menace is the fact that if allowed to grow, they extract from the soil much of the available nourishment. Much time has to be spent in destroying them or in trying to keep them in check. Children may not like the constant work of weeding a garden, but as they get older, they realize the importance of this work if they want to have a good garden crop.

230. **Do bacteria aid us?** When a plant or an animal dies, bacteria, which are microscopic, one-celled plants, start to grow in the organic stuff and cause the decay of whatever is left on or in the ground. There is usually an offensive odor connected with decay, but we should remember that eventually the soil is made more fertile through this action of bacteria. The chemical compounds of which the protoplasm was composed are broken down by the action of the bacteria. These substances then go off into the ground, ready to be used by growing plants to make more protoplasm. Under specially arranged conditions, certain kinds of bacteria and yeasts also produce alcohols by decay and *fermentation*.

It is very difficult to return nitrogen to the soil, yet, as you have learned, nitrogen is the most important element for soil

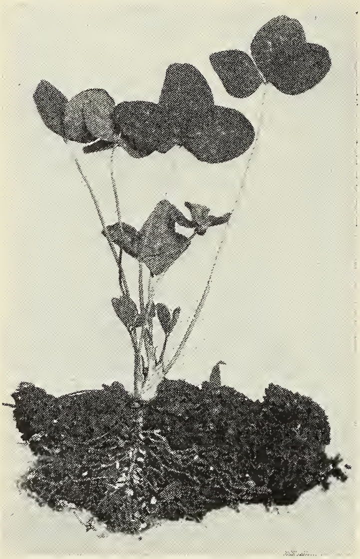


FIG. 16–9. The white swellings, or nodules, on the roots of plants such as this clover contain certain nitrogen-fixing bacteria. These bacteria change the nitrogen of the air into compounds that plants can use for food. That farmer who grows a crop of clover every few years is putting nitrogen into his soil at the same time that he is growing hay for his cattle. (*Courtesy U. S. Bureau of Plant Industry*)

fertility. Bacteria in the roots of legumes (lĕg′ūmz) – peas, beans, vetch, and clover – are able to return nitrogen to the soil. Land where such plants grow, therefore, is made richer rather than poorer by the cultivation of these plants. [See Fig. 16–9.]

231. How may foods be preserved from the action of bacteria? Bacteria, just referred to, may cause decay of foods and other products. Men have devised four main ways of preserving food and destroying bacteria.

a) Bacteria cannot thrive in low temperatures. Hence if the food is frozen, as many articles of food are, it will keep indefinitely. Our refrigerators do not usually reach the freezing point, but their lowered temperature prevents the action of bacteria for a considerable time.

b) Bacteria not only require warmth, they need moisture. Hence, if the food product is thoroughly dried, bacteria do not act on it. Dry foods such as cereals, flour, and sugar keep perfectly so long as no moisture penetrates them. Dried

fruits and *dehydrated* foods are examples of the application of this principle.

c) There are some *preservatives* like salt, sugar, and smoke that are not favorable for the growth of bacteria. So salted meat or fish, fruits preserved in sirup, and meats such as smoked ham, are well protected against decay.

d) Probably the safest method is to kill by heat all bacteria that may be present in the food, then seal the food quickly to prevent the entrance of other bacteria. This is the method most commonly employed in the canning industry. The food to be canned is usually heated by steam.

232. How may microscopic plants cause diseases in animals and in plants? Sometimes the bacteria grow too abundantly in the structures of plants or in the bodies of animals. Under such conditions they may get the upper hand and cause diseases. This is especially likely to result if the bacteria produce poisons called *toxins* (tŏk′sĭnz). Special substances called *vaccines* (văk′sēnz) and *serums* (sēr′ŭmz) are used to combat the growth of harmful bacteria in the bodies of animals, particularly of human beings. There are certain other tiny plants, not bacteria but equally small, that cause damage to many plants and animals. Among these enemies are rusts, smuts, and molds. Men have had to resort to poisons sprayed on plants to prevent these foes from destroying valuable plants and crops.

233. Are there plants poisonous to man? Poison ivy has been mentioned in a previous chapter. Poison sumac (sho͞o′-măk) is another plant poisonous to the touch. Nettles are very irritating to the skin. There are also many plants which contain substances which are poisonous if eaten. Some of these are the Amanita and other mushrooms, the deadly nightshade, nuts of the horse-chestnut tree, poison hemlock, loco weed, and Jimson weed. It seems rather strange that

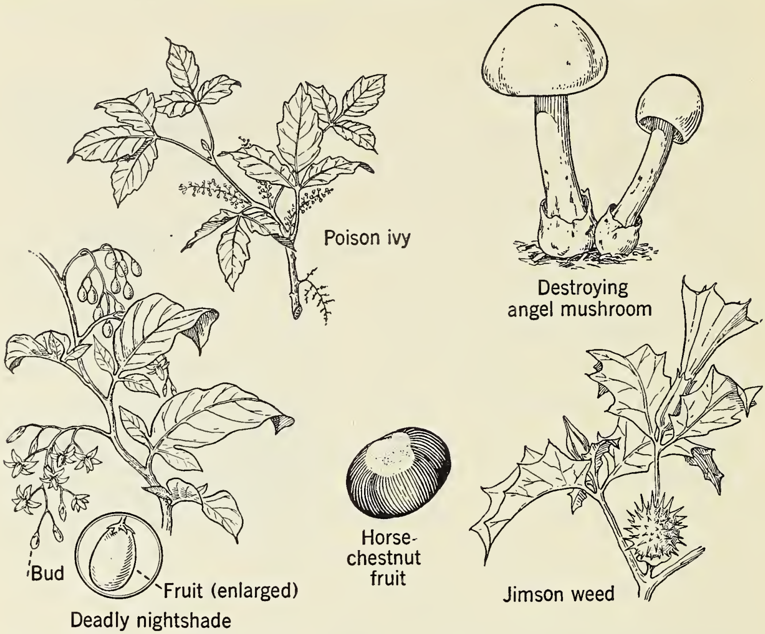


FIG. 16–10. Have you ever seen any of the poisonous plants shown in this diagram? Poison ivy is probably the best known to you because it grows in woods and vacant lots all over the United States.

birds can eat the berries of poison ivy, as many of them do, with no harm to themselves; that cattle and donkeys do not mind eating thistles; and that certain insects can gorge themselves on so-called poisonous mushrooms without bad effects on themselves. [See Fig. 16–10.]

234. What are some of the scientific aids for agriculture? In spite of the harm possible from certain kinds of plants, man has learned how to control most of his plant enemies, and to train his plant friends to yield even greater benefits to mankind.

As a result of scientific research, new uses have been found for many plants. By cultivation, man has learned to improve plants so that they have become far more valuable. The

sugar beet that is grown today, for example, is far richer in sugar than the first beets cultivated. A special wheat has been developed which is resistant to rust. Hybrid corn has been developed. Other examples might be mentioned.

There are many colleges and agricultural schools where anyone may learn the secrets of how to produce the best possible plants under given conditions. The great Department of Agriculture of the United States, upon request, will furnish information about its field of work, and will assist in solving the agricultural problems of all citizens, anywhere in the country.

Questions

1. Can you name two plants from the fibers of which baskets are made?
2. Can you name five trees, native to the United States, that are valuable for lumber?
3. Can you name five tropical trees that are valuable to man?
4. Make a list of the other uses of trees.
5. How do deciduous trees differ from evergreens?
6. What methods should be used to conserve our forests?
7. How is rubber obtained?
8. How is paper manufactured?
9. Make a list of all the weeds you have ever seen. How many of them grow in your garden?
10. Do you know the story of the formation of coal?
11. What is meant by cereals? Why are they so important?
12. Why are dyes valuable? Name one or two plants that furnish dye.
13. Can you name the different kinds of clothing which are made from plant fibers?
14. Name several medicines derived from plants.
15. List the native plants and vegetables in a market you know.
16. From the plants or plant products sold at this market can you select those that are imported?

17. The making of substitutes for lard is a comparatively new industry. Try to find out how one of these substitutes is made and from what raw materials.

18. How many agricultural schools or colleges has your state? Where are they located?

19. Why is it true that man could not live in a world without plants?

20. What do you think is the most valuable product obtained from plants?

Some things for you to do

1. Make a visit to a sawmill, if possible, and write an account of how a log becomes boards.

2. With the help of others, make a list of the different kinds of wood found in the structure of your house and in the furniture and the tools.

3. Make an exhibit for your school of the different stages in the making of rope or twine. The necessary materials can doubtless be obtained from a manufacturer of these products.

4. Read all you can about the making of paper. Then, if possible, visit a paper mill. Afterward write a composition on the making of paper.

5. If maple sirup is made in your vicinity, by personal inspection find out all you can about the method. Then write a composition on the making of maple sirup.

6. Pull up a clover plant and wash off the soil from the roots in order to see the nodules on the roots.

Animals Too Are Important to Us

Plants, as you read in the last unit, are of great importance in our lives. Animals too are important. In studying this unit you will understand that there is a sort of family relationship between man and animals, especially the higher animals that show intelligence.

Man has always been interested in animals. He has tried to protect the ones that have been most useful to him. By scientific breeding, he has been able to produce new kinds of animals. He has kept new forms of animals from perishing, as they might have done. The beautiful, slow-moving fan-tailed goldfish is one of these newer forms. It would soon have been eaten if it had been left exposed to enemies in streams and ponds. Another kind of animal which has survived through man's protection is the hornless cattle. These cattle were deprived by nature of their best weapon of de-

fense; but man liked them and found them useful and therefore helped them to survive.

Wild creatures such as fish, wild birds, deer, and other game might vanish if man did not protect them by conservation laws which all good citizens are glad to obey.

Certain other animals are carefully studied by scientists because these animals are harmful to human beings and must be controlled.

Think about these!

1. Do you know of any animal that can grow a complete new animal from only a piece of its body?
2. Are there any animal's eggs that do not have shells?
3. What animals that you know of are born blind?
4. What living creature is the most helpless when young?

Words for this chapter

Amoeba (ȧ·mē′bȧ). One of the simplest known animals, consisting of only one cell. It reproduces by dividing into two parts.

Asexual (å·sĕk′shōō·ăl). Without sex; used to describe reproduction without eggs and sperms in both plants and animals.

Fertilization. The union of a male reproductive cell with the nucleus of a female reproductive cell.

Sperm (spûrm) **cells.** The male cells which fertilize the ova, or eggs.

Mammal. A member of the highest group of animals, whose young are born alive and are nourished on milk by the mother animal.

Embryo (ĕm′brĭ·ō). A very young animal, before it is hatched or born. The term also applies to the young plant in the seed.

CHAPTER 17 ——— UNIT 8

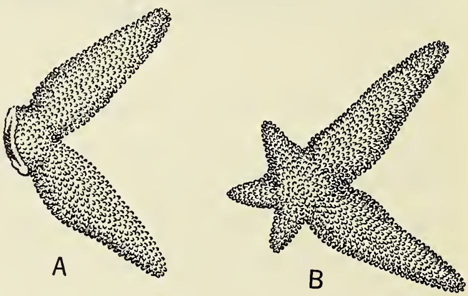
How Does Animal Life Begin?

235. What is the simplest method of animal reproduction? Animals reproduce in several ways. The simplest method is similar to the one you would use if you wanted to make two pencils out of one pencil. You would break or cut the pencil into two pieces. Animals like the *Amoeba* and Paramecium divide into two parts, each of which soon becomes full-grown. [See Fig. 17–1.] You would not know anything about this strange thing unless biologists had watched the process taking place under the microscope. If the starfish, an animal common along most seacoasts, is broken or cut into pieces, as the potato was (see Section 218), each ray or large portion will have the ability to develop into a complete starfish having five rays. [See Fig. 17–2.]

A curious flatworm, gray in color and an inch or so in length, is usually found in ponds. This animal, called *planaria* (plȧ·nā′rĭ·ȧ), can reproduce in the same way. It does not naturally divide into two parts as does the Amoeba, but

FIG. 17–1. The Paramecium, which is found in stagnant pond water, reproduces by dividing in the middle, forming two animals from one. In the upper left of this photomicrograph a Paramecium has just begun to divide across the middle of its body. The next time you have an opportunity, collect some pond water and bring it into the laboratory to examine. You will have to use a microscope to see Paramecia, because these one-celled animals are exceedingly small. (*Courtesy I. A. Herskowitz*)

FIG. 17–2. In *A* we see a starfish that has lost three rays. In a short time three new rays will have started to grow, as seen in *B*. In time a complete starfish will have developed from the original remnant.



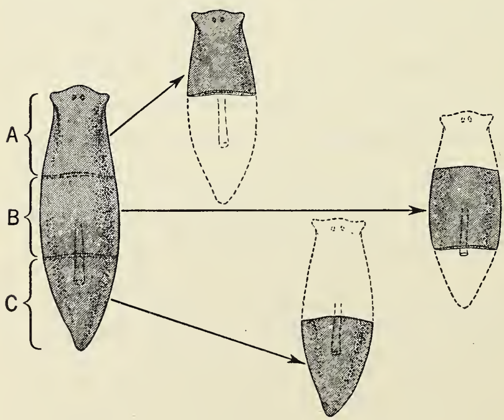


FIG. 17–3. The planaria, a small water animal, can reproduce from a piece of its own body. The diagram shows how each of the three pieces can grow the part missing. You can prove this in the laboratory. Cutting the planaria will not cause it any pain.

it can be cut into sections by the use of a pair of scissors, apparently without experiencing any feelings of pain which a higher animal would certainly show. [See Fig. 17–3.] And if this cutting has been done in the biology laboratory with care, each section, if kept in water and given food, gradually grows into a complete worm like the original. Some persons think that if an earthworm is cut into any two parts, each part will develop its missing section. However, biologists find that only the forward part will live, and that what happens is really recovery from injury, not reproduction. Each of these methods of reproduction is a very simple way of forming a new animal. Such methods are sometimes spoken of as *asexual*. This also applies to plants. (See Section 218.)

236. What special reproductive cells are formed by animals? Just as the flower produces ovules, the female animal produces reproductive cells called *eggs*. The male animal produces reproductive cells called *sperms*. Each sperm has a nucleus similar to the sperm nucleus of the pollen tube in a flower. Sperm cells are so very small that they can be seen only by using a microscope. Each animal sperm cell has a hairlike part by means of which it is able to move about.

Undoubtedly the eggs you know best are hen's eggs, common in every diet. If you have ever eaten shad roe, a great delicacy, you must have noticed that this food consists of many thousands of tiny eggs. Caviar consists of the much larger eggs of the sturgeon, another fish. Most boys and girls have seen the clumps of frog's eggs laid in ponds and streams in early spring, or the long strings of toad's eggs laid in the warm, shallow water of ponds later in the spring. [See Fig. 17–4.]

When fish lay their eggs they are said to be *spawning*. During the spawning season fishermen are forbidden by law

Fig. 17–4. The wood frogs in this picture are typical land frogs. They lay their eggs in water. The eggs at the lower right have been laid only a few hours; those above have been in the water longer. (*American Museum of Natural History*)

from catching edible freshwater fish, because of the danger of killing both parents and innumerable offspring.

237. How many eggs do individual animals produce? Birds usually lay from 3 to 5 eggs in a nest. Most insects lay hundreds of eggs. Fishes generally produce thousands of eggs, and even millions in the case of the cod and the eel. The common oyster, however, has the record with about 50,000,000 eggs.

238. Why is fertilization important? You will recall that a new seed cannot grow in the base of a flower unless a tiny ovule has first been fertilized by a sperm nucleus from the pollen tube. Similarly, an egg cannot begin to change into a living animal unless a sperm nucleus unites with its important egg nucleus. Reproduction by means of eggs and sperms is called *sexual reproduction.* In the case of water animals such as fish and frogs, their eggs are fertilized in the water shortly after being laid. In the case of the eggs of insects,

reptiles, and birds, which have a shell to keep the contents from drying up in the air, the eggs are fertilized before being laid.

Most fertilized eggs require warmth in order to hatch, and their contents must be kept moist. The eggs of most water animals like frogs, toads, and fishes are warmed by the gentle heat of the sun and usually hatch in a few days. The fertilized eggs of the trout and salmon, however, normally hatch in ice-cold water, weeks after being laid. The alligator, our largest reptile, places her eggs in a mound of decaying material that produces some heat of its own. The eggs of birds are hatched by the warmth of the mother's body. The process of keeping them warm by sitting on them is sometimes called *incubation* (ĭn′kū·bā′shŭn). After incubation starts, birds' eggs must not be allowed to get cold, since this would be fatal to the young bird in the egg. We should never keep an incubating wild bird away from its nest of eggs. [See Fig. 17–5.]

239. What is an embryo? After the nucleus of an egg has been fertilized, the egg cell begins to divide into many cells. Gradually these cells grow into an *embryo,* a tiny form which has the same name as is given to the baby plant in the seed. The embryo is shaped somewhat like the punctuation mark known as the comma. In a hen's egg that has been incubated a few days, the little embryo can be plainly seen, already red with blood and with minute blood vessels extending out from its beating heart like veins in a leaf.

After a period of development, varying from a few hours to several weeks, the baby animal emerges from the egg. Generally young animals have to shift for themselves in a world that seems to have no welcome for the millions of new creatures coming into existence each day.

Higher animals like the mammals, which consist mostly of

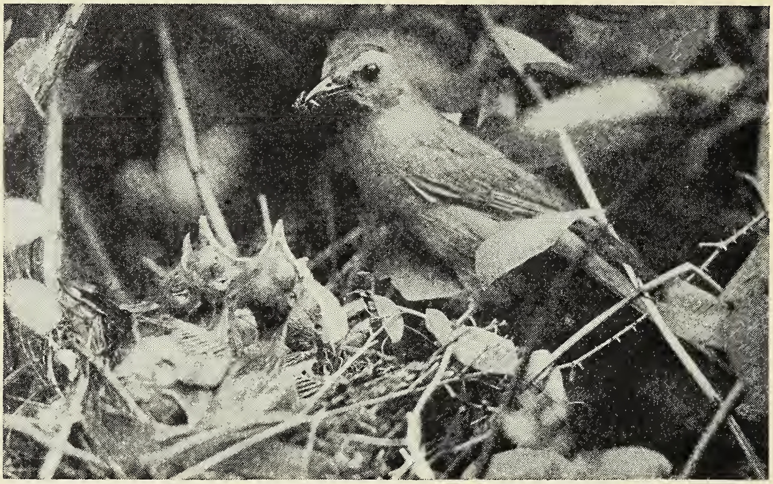


FIG. 17–5. These baby catbirds are all waiting with their mouths open for the food their mother has for them. The nest is their cradle, rather than their home. (*Courtesy U. S. Department of the Interior*)

four-footed animals, are born alive. The mother feeds them for a time with her milk, and usually both parents care for them in other ways. A few fishes, some snakes and spiders, and most birds also care for their young. Without such parental care many baby animals would certainly perish. Some mammals, like mice, rats, kittens, and puppies, are born blind and their eyes do not open for several days after birth.

For no other mammal is the period of helpless infancy so prolonged as it is for human beings. Perhaps because human beings are the very highest forms of life on the earth, it is necessary for them to have a long infancy and childhood in which to develop their bodies and train their minds for the important responsibilities they must assume later in life.

QUESTIONS

1. What do you understand by the phrase *asexual reproduction?*

2. What are two animals that reproduce asexually?

3. What are two differences between sexual and asexual reproduction?

4. Are there any differences in fertilization as it occurs in plants and in animals?

5. Are there any resemblances in fertilization as it occurs in plants and in animals?

6. What female animal produces the largest number of eggs?

7. Name two animals that are born blind.

8. Among mammals, what special food is furnished by the female to her young?

SOME THINGS FOR YOU TO DO

1. Gather some frog's eggs that have been laid in a pond or a stream in the woods, in the early spring. Keep them in a jar of water and watch the eggs hatch into tadpoles. Get some water plants, also, from the place where you found the eggs and put the plants into the jar with them. The tadpoles which hatch out will use the plants for support and for food.

2. If your cat has had a litter of kittens, or if your dog has had a litter of puppies, describe some of the ways in which the mother expresses affection for the young animals.

3. If you have kept guppies, which release their young alive instead of laying eggs, you may have watched the young fish. Tell how the parents behaved toward them, and describe the actions of the young fish.

Think about these!

1. What animal was probably the first to be domesticated?
2. How might a king snake take your cat's place?
3. Why is it better to kill a female fly at the beginning of the summer than at the end?
4. From what is glue obtained?

Words for this chapter

Tanning. Changing the skin of an animal to leather, by means of a chemical process.

Economic. Having to do with the satisfaction of our needs.

Parasite (păr′*ȧ*·sīt). An animal or a plant which lives on another animal or plant.

Pupa (pū′pȧ), *plural,* **pupae** (pū′pē). The stage in the life of an insect that precedes the adult stage. It follows the larva.

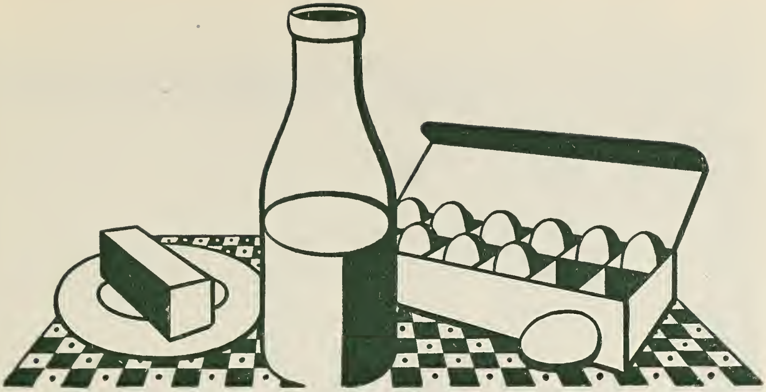
Larva (lär′vȧ), *plural,* **larvae** (lär′vē). The second stage in the life of an insect, following the egg.

Defoliate (dė·fō′lĭ·āt). To strip the leaves from.

Host. The animal or plant on which a parasite lives.

Propagation (prŏp′*ȧ*·gā′sh*ŭ*n). Reproduction, under man's care, of organisms.

Heritage (hĕr′*ĭ*·tĭj). A possession by birthright.



CHAPTER 18 ______________ UNIT 8

In What Ways Do Animals Help or Harm Us?

240. How do animals aid mankind? In a preceding chapter it was shown that all animal life is directly or indirectly dependent upon green plants for food. In that sense man is probably more dependent upon plants than upon animals. Yet there are hundreds of important ways in which animals affect mankind. Many products such as glue, oil, wax, and lacquer, are obtained from animals. Some animals supply us with food. Others serve as beasts of burden, carrying or hauling loads that are too heavy for man. Certain friendly animals protect man from other and dangerous animals. The fur-bearers furnish us with warm clothing. From others we obtain leather. Some animals are interesting pets, and a few even become man's associates.

241. Are animals a source of food for man? In the first place, animals are a vital source of food supply. Various

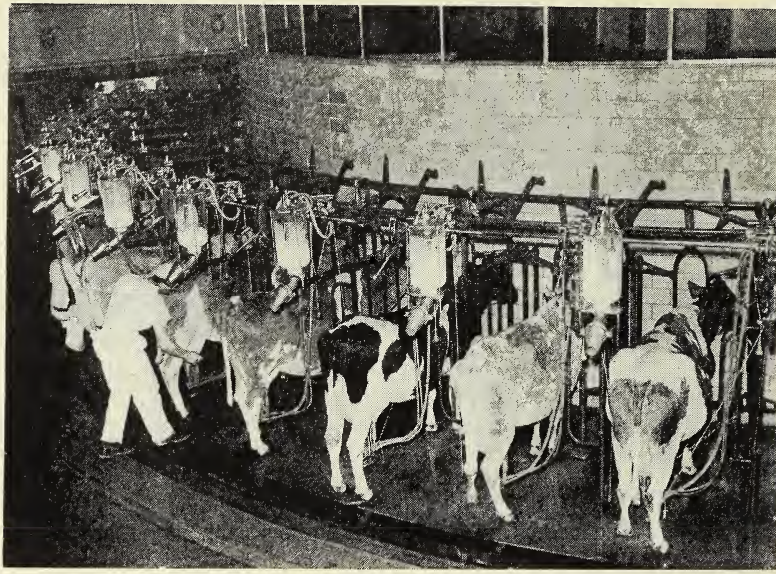


FIG. 18–1. In a modern dairy barn, cleanliness is emphasized everywhere. The cows are washed before being milked, attendants wear white uniforms, and the milking is done by machines. (*Courtesy The Borden Co.*)

kinds of meat, fish, and fowl, together with milk, butter, cheese, and eggs, are probably the most important items of daily food for most persons in civilized countries. Billions of pounds of milk are sold annually in the United States. Almost everyone in the United States eats many pounds of butter in a year. No farm animal is more useful than the cow, which produces nearly all our milk, butter, and cheese. [See Fig. 18–1.] Large herds of steer roam over western grazing lands or are fattened on the farms of the Middle West. These animals are our chief supply of meat. Other animals also are used for food. It takes the farmer about two years to get a steer ready for the market, but in about six months he can grow a pig and have one hundred and fifty or more pounds of meat ready for the market. It

has been said that the large packing houses of Chicago use every part of the hog except the squeal. The bristles are used for brushes, the bones for fertilizer, the lard for a cooking fat, the pepsin from the stomach for medicine or in chewing gum, the skin for the finest kind of leather, the flesh for bacon, ham, sausage, and pork.

The sheep is another animal that the farmer can grow quickly. Lamb chops bring a high price, but unfortunately the butcher cannot cut up the whole carcass of a sheep into lamb chops. From the sheep we also get wool, which is spun and woven to produce our warmest clothing.

Did you know that a good hen will lay two hundred or more eggs each year? That number of eggs alone will supply a hungry man with protein for breakfasts for several months of the year. Through scientific breeding and care, the poultry business has now become one of the leaders in the United States.

There are many strange foods of animal origin that are consumed in different parts of the world. In Africa and Asia, grasshoppers are a regular food for some tribes. In Central America, lizards called *iguanas* (ĭ·gwä′nȧz) are highly prized. Many of the peoples around the Mediterranean are fond of squids. In the Far East a soup made of birds' nests is considered a great dainty.

242. How much of our clothing comes from animals? For clothing, man is largely dependent upon animals. Wool is obtained from the hairy covering of sheep, silk from the cocoon of the silkworm, furs from a dozen or more hairy mammals called *fur-bearers*, hairs for felt hats from rabbits, and feathers from the ostrich and domestic birds.

Unfortunately, in a number of countries the plumage of wild birds is used. If too many birds in a species are captured, the species will die out. Leather, used for clothing and

FIG. 18–2. The fur-bearing animal in this picture is a flying squirrel. Instead of depending entirely on his feet for locomotion as red and gray squirrels do, he leaps from tree to tree. The hair-covered winglike membranes between his front and rear feet help him to glide from place to place, although he cannot actually fly. The fur of squirrels is often used for coats and wraps. (*American Museum of Natural History*)

for a vast number of other purposes, is made from the skin, or hide, of certain animals, mostly cattle, by a process called *tanning*. So-called "pearl" buttons are cut in enormous numbers from the shells of fresh-water clams.

Nearly everyone likes to read stories of the hunters and trappers of the Northwest. Since the discovery of America, men have roamed the forests in their search for fur-bearing animals. The list includes the fox, raccoon, skunk, muskrat, beaver, mink, otter, squirrel, rabbit, marten, sable, and some others found in America. From other lands there are many more. The fur trade amounts to many millions of dollars annually. [See Fig. 18–2.]

As the country has become more thickly populated and more and more of the forests have been cut down, the fur-bearing animals have become scarce. To supply the demand for furs, fox, mink, and skunk farms have become more numerous. The growing of such animals for their furs has proved profitable when it has been done scientifically. [See Fig. 18–3.]

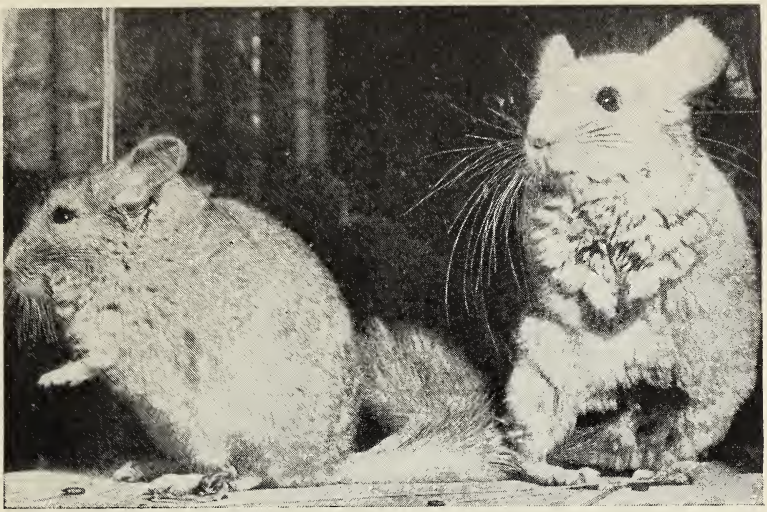


FIG. 18–3. These little animals are chinchillas. They belong to the rodent group, as do mice and squirrels. Chinchillas are valuable animals; in fact, they are said to be worth their weight in gold. Chinchilla fur is pearl gray, and is deep and silky to the touch. Coats and capes made of this fur are expensive because the animals are so rare and hard to raise. (*Courtesy Graef Chinchilla Ranch*)

243. What animals are pets and friends? The dog has long been man's companion and useful friend. It is true that he may carry fleas and that he may become vicious at times, but his usefulness is well known. He goes with man to the coldest parts of the globe where he pulls the sleds of the Eskimo and the traveler in the frozen northlands. He is also found in the tropics as a member of every wild tribe of savages and group of civilized men. He saves a child from drowning, and he rescues the Alpine climber lost in the snows. He watches the flocks of the farmer and brings the cows from their pasture. He stalks the game for the hunter. He guards property and life and in many cases is faithful until death.

The cat is nearly as widely distributed throughout the world as is the dog. The cat makes an interesting pet, though it lacks the activity and intelligence of the dog. Although the cat is valuable as a mouser, it catches so many insect-eating birds that it is probably more harmful than useful, at least in the springtime. Bird lovers should tie a bell around the neck of even the most gentle cat at this time of year, if the animal has access to places where songbirds breed.

Canary birds and parrots are quite common in homes throughout the world. If you buy a parrot, you should make sure that it is not a carrier of the germs of so-called "parrot fever," or *psittacosis* (sĭt′ȧ·kō′sĭs). Monkeys make excellent pets if they are tamed when very young. A few persons have been equally successful with apes, particularly the chimpanzee, which is a very intelligent creature. Almost everyone has kept goldfish or tropical fish. An animal which may seem strange as a pet is the king snake, a harmless yellow and brown reptile, which, surprisingly, is a better mouser than any cat.

244. What animals are used as beasts of burden? In the United States there is now one motor car to every fifth person in the entire country. It might seem to any boy or girl that, with the popularity of the automobile and the introduction of the farm tractor, the demand for horses must have stopped. However, almost every farmer still has several horses which he requires for many kinds of work about the farm. Horses for cavalry and mules for general work are required in armies. The mounted policemen in the large cities must have the best of horses. If we were to go to a country where there were few motor vehicles, we would see how greatly men there depend on donkeys, horses, oxen, dogs, water buffalo, reindeer, camels, and even elephants to do most of their heavy work. [See Fig. 18–4.]

FIG. 18–4. A patient water buffalo drawing a plow in a rice field in the Philippines. The women in the foreground are setting out young rice plants. Much water is necessary for growing rice, and irrigation is usually necessary. (*Ewing Galloway*)

245. Of what value are birds? In parts of the United States where winters are cold, almost everyone is on the lookout in early spring for the first returning song sparrow or robin. Some of the migrating birds, such as the swallow, return almost exactly on the corresponding date, year after year. All of us are glad to see the birds, after their absence of six months, because birds are our friends. We love their songs, the most beautiful carols in the world. The colors of the jaunty males rival the rainbow. Yet it is not alone for their melodies that birds are loved. There are more practical reasons. Insects are the worst enemy that agriculture has to face. Birds destroy more obnoxious insects than any other agency of man or nature. Out in Salt Lake City, the

grateful Mormons erected a monument to the gulls that had saved the lives of the members of the little pioneering band when they first settled in what is now the state of Utah. Huge swarms of grasshoppers and crickets were eating their only crops despite all their efforts. As if in answer to their prayers and while they were still on their knees, great flocks of gulls appeared and made short work of the insects.

246. Why are insect-eating birds the most valuable? There are many kinds of wild birds that have a diet almost entirely of insects. They include the wren, chickadee, woodpecker, flicker, vireo, nighthawk, kingbird, meadowlark, swallow, and many others. It has been estimated that if the birds were suddenly all destroyed, insects, unchecked by birds, would increase so rapidly that they would quickly destroy all plant life, and that within from three to five years' time there would not be a grass blade or any other green leaf left alive. In plain English, that would mean the starvation of the entire human world! Insect-eating birds, then, from the *economic* standpoint alone, are invaluable to us. [See Fig. 18–5.]

FIG. 18–5. This robin is bringing a dragonfly to its hungry young. Perhaps there is a robin's nest near your home. In the springtime you can see the mother robin catching insects and pulling earthworms up out of the ground to feed herself and her young. (*Courtesy U. S. Department of the Interior*)

Such birds are especially valuable during the breeding season, when they have to find food not only for themselves but for their hungry young. If you can watch a nesting box occupied by a pair of wrens, you will find it interesting to count the number of times the parent birds bring food home to the young birds. If the young are at least half grown, you will probably find that worms, spiders, and adult insects are being brought by the parents at intervals of only three to five minutes all day long. Young birds are prodigious eaters. Naturalists tell us that some of these infants have been known to eat *nine times* their own weight of food in twenty-four hours. A pair of bluebirds will keep an orchard fairly free from the codling moths, the young of which are the common "apple worms."

247. Do some birds eat weed seeds and rodents? One seventh of all the birds belong to the group known as *sparrows.* But not all sparrows are English sparrows. A sparrow can be recognized by its blunt, heavy bill. This kind of bill is an excellent adaptation for opening seed husks and for crushing seeds. The sparrows and many other birds, such as the quail, bluejay, red-winged blackbird, grackle, cedar waxwing, and crow include seeds in their diets. Such birds find food in the winter in the seeds left in the dry tops of weeds that rise above the snow. After a snowstorm, you will find footprints of these birds in circles around such breakfast tables. [See Fig. 18–6.] Boys who do not usually throw their hats in the air at the prospect of weeding the garden should be the first to thank the seed-eating birds for their assistance in eating weed seeds.

Another group of birds, the *hawks,* contains many members to which we are indebted. The farmer may not always agree with Dr. Chapman, the eminent Curator of Birds of the American Museum of Natural History, New York City, in his

FIG. 18–6. The bird tracks in the snow around this weed show that shore larks have been about. Do you know why they came here? (*American Museum of Natural History*)

statement that ninety per cent of all hawks are helpful to man. The farmer blames all hawks because from time to time he loses a chicken from his flock. He sees the red-shouldered hawk or the red-tailed hawk high in the sky, or the marsh hawk flying low over his meadows, and he shakes his fist at what he supposes are his enemies. But these hawks are really his friends. Their food consists almost entirely of field mice, rats, and large insects. Field mice are among the worst enemies of agriculture. They eat standing grain and corn, and also gnaw and spoil stored crops. If the farmer were to hire allies, he could not improve upon the assistants nature has given him, who work overtime without pay and

never strike. There are a few hawks, all smallish compared with those just mentioned, that do snatch chickens and song-birds. They are rapid fliers and usually escape into trees with their booty without being seen.

248. **Can boys and girls help the birds?** There are many ways in which young people who know the great importance of wild birds can help their cause. Many of the birds accept birdhouses put up by some bird lover. It should be remembered that if you are erecting a birdhouse for wrens, the opening made must be too small to admit an English sparrow, who, if he can enter, is likely to drive the wrens away. Most of the insect-eating birds leave us in the winter because the food supply of adult insects or partly-grown insects is no longer available. But there are nuthatches, chickadees, blue-jays, and others that stay through the winter, and they will be glad to find a piece of suet wired on a tree. Any butcher will give you a piece; so the project requires only a little planning and time.

In the summer the birds are glad to know where they can always get water. A birdbath is much appreciated by them, but it does not appear that they, like some humans, prefer a costly affair. The principal thing is the assurance that water can always be found at this particular spot. If you care to try the experiment, dig a shallow hole in the ground and place there a small pan; put some water into this pan every morning, and you will be rewarded when you see the birds bathe and drink. Perhaps you will be able to take some photographs of these birds, by placing your camera, previously focused, and then releasing the shutter by pulling a long thread attached to it. Be sure that this pan of water does not breed mosquitoes.

Every boy should know that it is strictly against the law to collect the eggs of wild birds or to harm them in any way.

In fact, every boy or girl who knows how indebted we are to the birds, will do everything in his or her power to protect them.

249. How do some insects aid man? Some insects are of great value to man. It would be difficult to have fruit in an orchard, or to get seeds on most plants without the influence of insects. The bee, as she goes about from flower to flower, gets her hairy coat dusted with pollen grains. These are caught on the pistil of the next flower, and thus cross-pollination and fertilization are made possible with resulting fruit and seeds. The bee does not know that she is aiding man. She is merely hunting for nectar found in almost all flowers. This nectar is taken by her to the hive and there is changed into honey. The honey is packed into cells and later used as food for the hive, unless man takes it away for his own use. In that case the bees make more. Beeswax is a by-product of making honey. Man uses it in a number of ways. The colonial life found in a beehive is one of the best examples of co-operation to be found anywhere in the world. Certainly no human society has yet learned to work in such harmony as do the bees, where 40,000 individuals may live together in one hive.

In 1886 the orange industry of California was threatened with extinction. A scale insect was killing the orange trees in spite of all that could be done by frantic fruitgrowers. Ladybugs called *Vedalia* (vė·dā′lĭ·*ȧ*) were found in Australia and imported to California in the hope that these little beetles would eat up the scale insects. The experiment was entirely successful, and ladybug insects have been used in all parts of the world since then to control scales and some other insects.

Several insects have been found useful because they prey upon injurious species. The Calosoma beetle has proved very successful in the control of gypsy and brown-tail moths

Fig. 18–7. One of our most helpful insects is the Calosoma beetle, shown here eating a caterpillar of the brown-tail moth. (*Courtesy U. S. Department of Agriculture*)

in New England. [See Fig. 18–7.] A tiny insect called the *ichneumon* (ĭk·nū′mŏn) *fly* lays its eggs in the bodies of tent caterpillars, which are thus destroyed. The praying mantis, " daddy longlegs," and, to a small extent, spiders, are beneficial. [See Fig. 18–8.] At the present time we need to find an insect that will live as a *parasite* on the destructive Japanese beetle and also on several other common pests, such as the fly and the mosquito.

250. Do snakes, toads, and frogs aid man? Are you aware that the snake, which boys in the country may sometimes stone, is one of your best friends? You know that many

Fig. 18–8. The praying mantis gets its name from the unusual position it often assumes: it folds its forelegs together like hands folded in prayer. Many of the insects it eats are harmful; so the mantis is actually helpful to man. In the fall of the year, the mantis makes a soft cocoon, in which it lays its eggs. In the spring, many little mantes leave the cocoon, and go in search of food. (*Science Service*)

of the insects are man's most serious living menace among other forms of life; it should be self-evident that animals that destroy injurious insects are man's friends. Snakes eat insects and field mice. Some snakes eat frogs and toads when they can get them. Four kinds of poisonous snakes are found in the United States: the rattlesnake, the water moccasin, the copperhead, and the coral snake. These snakes are not such a menace as many people think. When they eat frogs and toads, however, the snakes are really injurious to us, because these animals are almost entirely dependent upon insects for their food. It is said that a toad will eat enough to fill its stomach three or four times during a single night. Such a creature is worth its weight in gold in a garden.

251. What special products are obtained from animals? Pearls are produced by the so-called pearl oysters. Pearls are also made by fresh-water clams. The pearl grows at the spot at which the oyster has been injured by a grain of sand or some other substance. It takes so long for pearls to grow in pearl oysters that the Japanese have introduced grains of sand and other materials into oysters, and thus have induced them to start to make pearls. They also have introduced small images to be coated with pearl. Recently a new industry has developed, that of making artificial pearls from fish scales. From whales, oil and a high grade of wax are obtained. Ivory is still secured from African elephants, though the supply of animals is dwindling. Horns and antlers furnish materials for handles of knives, bow tips, and various ornaments. We get glue from the hoofs of animals, and gelatine from bones.

252. Are many animals man's enemies? But not all animals are man's friends. There are a great many which harass or annoy man, and some that are dangerous to him. The large fur-bearers, like the lion, tiger, panther, and wolf, un-

FIG. 18–9. The common rat has been called the worst pest among mammals. Rats are said to eat and destroy more than two million dollars worth of food and manufactured goods in a year. (*Courtesy American Museum of Natural History*)

der certain conditions, do not hesitate to attack man as well as his domestic animals. Rats are destroyers of enormous quantities of food and manufactured articles; they also harbor fleas which themselves may be the carriers of the germs of the bubonic plague. [See Fig. 18–9.] The tapeworm, the pork worm, and the hookworm are three of many other parasites which trouble man. Poisonous snakes kill many thousands of persons in India every year. There are many other animals with which man has to contend, but perhaps the insects are the most prominent.

253. Are insects the chief contestants with man for a place on the earth? Of all animals, insects are undoubtedly the most serious contenders with man for a place on the earth. Some of them are utterly obnoxious. They sting, bite, and poison man; they eat his plants together with his silk and woolen clothes; they make his apples wormy; they spoil much of his corn and many of his fruits; they render shrubs and trees leafless; they disfigure the landscape with webs and caterpillars; they destroy wood; and they carry harmful germs to man. In brief, it is only by constant warfare and extreme vigilance, for which man has to pay a high price, that he can control them. Dr. L. O. Howard, formerly the Head of

the Bureau of Entomology at Washington, said " Insects are winners in life's race." There are 15,000 species of insects within fifty miles of New York City, many of them harmful to man.

254. What is the life history of an insect? If we study the life history of a typical insect, we shall better understand why insects multiply rapidly in spite of man's efforts to check them. Let us take the mosquito as an example. In places where there is a winter season, a few mosquitoes survive by staying in the cellar of the house, or in the barn where cattle keep the temperature above freezing. As soon as warm weather comes again, the female mosquito lays her eggs, always on the surface of water. There are about 200 eggs in a tiny cluster that floats on the surface of any quiet water, whether in a swamp, an old tin can, or a rain barrel. Each egg will hatch in a few hours into an active *larva,* called a *wriggler.* [See Fig. 18–10.] This little creature has no gills to breathe the air dissolved in water; so it has to come up to the surface of the water at frequent intervals to get air. This air is taken into its body through a projection from the hind part of the body. If kerosene or crude oil has been put on the water, some of the oil is bound to get into this breathing tube and clog it. Thus, oiling the surface of mosquito-breeding places is one good method of destroying this insect.

After about a week, if all goes well, the larva changes into the *pupa* stage. In most insects, this pupa stage is a sleeping period while the insect is changing into the adult stage. However, the mosquito is an exception, and goes through this stage rapidly. The pupa looks like an exaggerated comma or question mark. It has a large head and two breathing tubes just back of the head. Now it has to come up to the surface headfirst for air. It lives as a pupa for only two or three days. Then a wonderful thing happens. The pupa

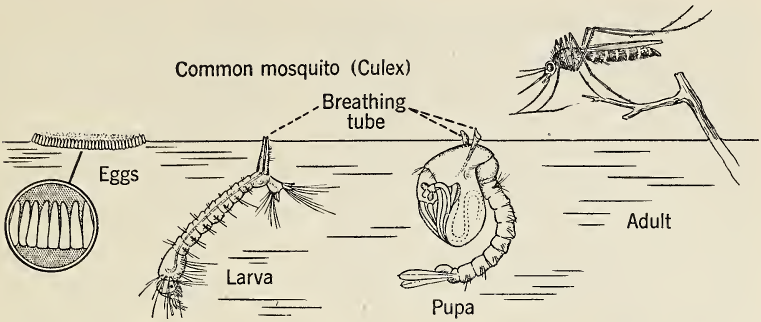


FIG. 18–10. The four stages in the development of the Culex, or common mosquito, are shown here. Since this insect comes to the surface to breathe air, it can easily be killed in the first three stages by a film of oil put on the surface of the water, where it breeds. Can you tell why? How can the adult best be killed? The eggs of the common mosquito are found in a cluster. Notice the position of the larva when it is getting air. The body of the adult is almost parallel with the surface on which it is resting. Why is it important to control mosquitoes? Is anything being done in your community to get rid of them?

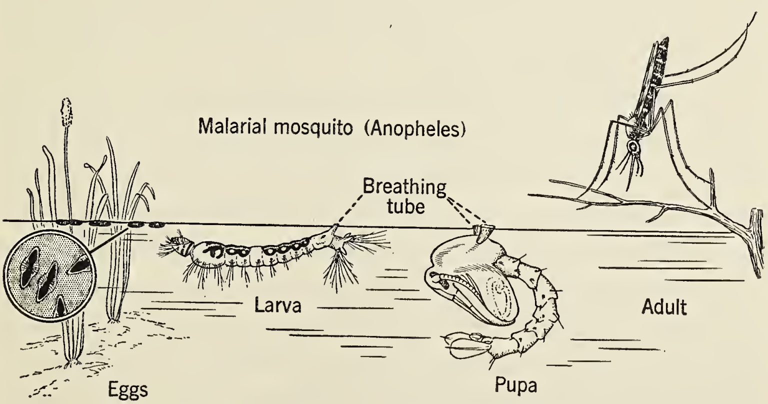


FIG. 18–11. The Anopheles, or malarial mosquito, has the same four stages of development as has the common mosquito. Compare each stage of the two mosquitoes to find the chief differences. Notice particularly the difference in position in the water and in the air.

comes to the surface never to descend again. The skin splits down the back, and the adult mosquito comes out, balancing itself on the cast-off skin of the pupa, which becomes a sort of raft. This is a very delicate operation, and many a newly hatched mosquito has been shipwrecked by a puff of wind that upset its tiny raft. In a few moments its new wings are dry; and if it is a female, it flies off to bite you or someone else, but certainly to fill itself with blood somewhere if it can find a victim.

From the time the eggs are laid until the adult mosquito emerges, only about ten days have elapsed. If each of the female descendants of one female mosquito lays 200 eggs, and if one half of these eggs develop into females who repeat the process, it is possible to have, in one month, more than 2,000,000 descendants from a single female.

The life history of the mosquito is typical of that of most insects, except that few develop in water. There are commonly four stages: the *egg*, the *larva*, the *pupa*, and the *adult*. There are a few insects such as the grasshopper, the cricket, the dragonfly, and some bugs, that have only one stage between the egg and the adult.

255. Why is the mosquito such a pest? It is annoying to hear a female mosquito sing, especially when we are trying to sleep. It is not pleasant to be bitten by a mosquito. Aside from the swelling and itching, it may be positively dangerous to be bitten by some kinds of mosquitoes. While the common mosquito, the *Culex* (kū′lĕks), is simply a pest, the *Anopheles* (ȧ·nŏf′ĕ·lēz) mosquito may be a carrier of the germs of malaria, and the *Aëdes* (ā·ē′dēz) mosquito frequently carries the germs of yellow fever. [See Figs. 18–11 and 18–12.]

The Anopheles mosquito is the cause of a great deal of suffering, especially in the warmer parts of the world. In the

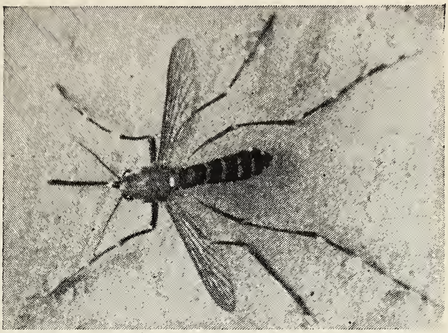


FIG. 18–12. This is an actual photograph, enlarged, of the Anopheles or malarial mosquito. Most insects which are dangerous to man would be avoided by all of us if we could see what they really look like. (*Courtesy U. S. Department of Agriculture*)

United States alone it is said that the annual loss from malaria amounts to $100,000,000. The Anopheles mosquito can be recognized because it rests with the hind part of its body tilted up in the air. When it bites a person suffering from malaria, the mosquito sucks in with the blood some of the spores of the malaria parasite. These spores grow and multiply in the body of the mosquito. If that mosquito bites a second person, some of these spores are likely to be introduced into the blood of the second person and may cause malaria. Without mosquitoes there could be no spread of this disease from one person to another.

The Aëdes mosquito similarly spreads the germs of yellow fever if it has previously bitten a victim of this disease. Fortunately for us in the temperate zone, the Aëdes is a tropical mosquito and does not usually appear in temperate climates.

256. What methods are used to control mosquitoes? Several methods are employed to keep mosquitoes in check:

a) *Natural enemies.* The bats that zigzag through air on summer evenings are catching insects, among them many mosquitoes. Dragonflies feed almost exclusively on mosquitoes. Swallows, nighthawks, and flycatchers are three birds that eat mosquitoes. Perhaps the chief enemies of mosquitoes, at least in the tropics, are the tiny fish known in northern states as *tropicals,* but which in warm countries are called

mosquito fish. Where drinking water is kept in cisterns, many localities require owners to keep such fish in the cisterns. These tiny fish are so fond of the wrigglers and pupae that they keep the waters clean. Of course entrances to the cistern are also screened.

b) *Draining and oiling.* The matter of extermination of mosquitoes is so important that many of the states have commissions to carry on this work. Real-estate values are greatly affected by the presence or absence of these pests. Since swampy places are excellent regions for breeding mosquitoes, such places are usually drained if they are not too low. With the water gone, mosquitoes are prevented from breeding and the land may be utilized. Where this course is not possible, kerosene or crude oil is put on the water. This rapidly spreads a film over the surface, which kills both larvae and

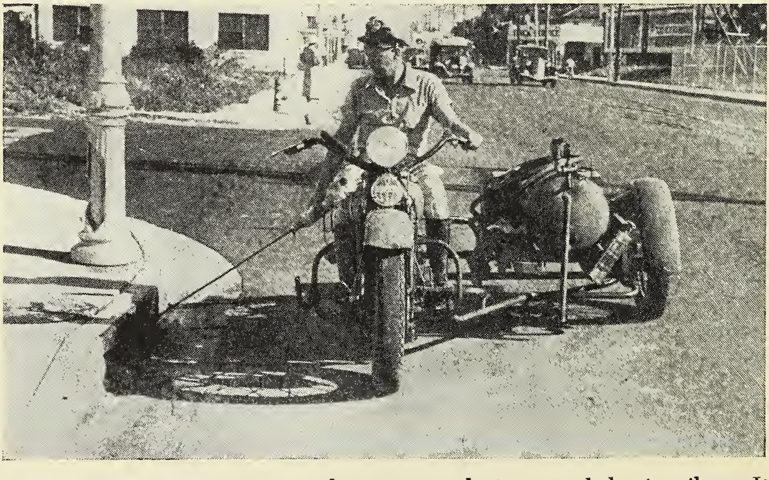


FIG. 18–13. The man on the motorcycle is a catch-basin oiler. It takes him only a few seconds to shoot a little oil into a sewer catch basin and thus destroy a mosquito-breeding place. He has a hose to reach the catch basins when cars are parked beside them. This method of mosquito control is effective in large cities. (*Courtesy U. S. Public Health Service*)

pupae by preventing their breathing. It also kills adult mosquitoes that get into it. However, this oil treatment is injurious to plants and fishes. [See Fig. 18–13.]

c) *Prevention of stagnant water.* The female mosquito does not require a whole swamp in which to lay her eggs. Any still water will do, even an old tin can, or water in a discarded pitcher or pail. If this water remains ten days, several hundred mosquitoes can be produced. Therefore it is not only in the interest of good housekeeping to dispose thoroughly of cans and rubbish; it is excellent biology and pays good dividends.

d) *Screening of houses.* By the use of screens, by no means a small expense for the country at large, mosquitoes and other insects are largely prevented from invading our houses.

e) *Use of chemicals.* If mosquitoes do get into our rooms, the use of oily sprays is very effective. The vigorous spraying of such preparations in a closed room will very quickly kill all mosquitoes and flies.

Mosquitoes are driven away by odors such as tar, pennyroyal, and citronella. While such remedies do not kill these insects, they tend to keep mosquitoes away.

f) *Use of fish.* Ponds may be stocked with goldfish or mosquito fish. By the co-operation of all persons in a community, young and old, any region can fairly easily rid itself of mosquitoes.

257. What harm do flies do? The common housefly is another insect, more of a nuisance, and certainly even more of a menace, than are mosquitoes. They breed in manure and filth, even feeding there. Their hairy bodies carry thousands of germs, many of them the dangerous kinds. They never clean their feet except by rubbing them together, and they never take a bath unless they happen to fall into the

baby's milk. Wherever they go, they distribute dirt and the germs of typhoid, cholera, tuberculosis, dysentery, and other intestinal disease. One authority states: "It has been proved that flies are responsible for the death of more people than all wild beasts and reptiles together, and that actually they are more dangerous to man than the tiger, grizzly, or rattlesnake." The man who invented the cardboard caps for milk bottles was stimulated in his efforts by the knowledge that hundreds of babies in a certain city had died because the milk given to them had been delivered in uncovered vessels.

Flies, if unchecked, reproduce at such unbelievable rates that unless the breeding flies can be exterminated, no progress can be made. For every one of the first spring flies we kill, it is well to remember that we are destroying a possible million flies. The facts of the life history of flies are simple. [See Fig. 18–14.] A female fly which has wintered in the

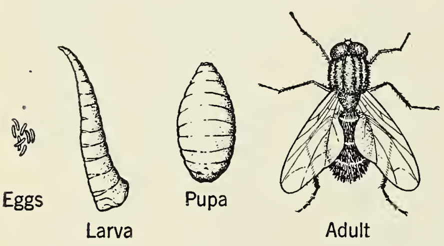


FIG. 18–14. The four stages in the life cycle of a fly.

cellar or other protected place begins to lay her eggs, from one hundred to two hundred in number, as soon as the weather gets warm in the spring. These eggs are deposited in horse manure, garbage, or filth of any kind. In a day they hatch into a white worm called a *maggot.* After eating and growing for five or six days, each larva changes into a sleeping stage, the pupa. After about a week the adult fly hatches. Thus the development takes two weeks. The same female fly may lay eggs every few days from spring until cool

weather in the fall. Thus one fly, if there were no deaths, could produce over two million million offspring in half of the summer.

258. How can we control flies? There are several ways to control the fly nuisance.

a) By destroying breeding places. Since most flies breed in stable manure, such refuse should be kept in covered containers, and removed every two weeks, or else sprinkled with chloride of lime every week. Borax in the proportion of one pound of borax per horse per week can also be used. Co-operation is essential, since one untreated manure pile can breed flies by the millions. Garbage pails must be kept covered. In small villages, and in the country where there is no sewage disposal, all waste matter should be covered.

b) By the use of traps and poisons. There are several kinds of wire traps for catching flies. Sticky flypaper is also effective. Poisons can be used. A two-per-cent solution of *formaldehyde* (fôr·măl′dė·hīd) in water, to which a little sugar has been added, will kill many flies. If you purchase the formaldehyde from the druggist, use one part to twenty parts of water. Electric fly killers are also effective.

c) By the use of screens. Food should always be kept away from flies, or better yet, flies should be kept away from food. This is usually done in most homes, yet vendors of food and drink who go about with carts may be distributing death with their wares. Nor are foods in stores always as well protected as the law requires. It is only by eternal vigilance, based on knowledge and co-operation, that such a menace as the fly can be controlled.

259. What are some other household pests? There are many other insects with which man has to cope. Although the adult clothes moth has no mouth parts, its larva eats woolens and furs, causing enormous losses. Science has produced

substances that if used in a closed place will kill the clothes moth in any stage. *Naphthalene* (năf′thȧ·lēn), commonly called " camphor balls," serves as a repellent. Other good repellents are now on the market.

Cockroaches have been a nuisance in homes for three hundred years, ever since Sir Francis Drake accidentally brought them into Europe from India. Insect powder checks them.

In some localities, lice and bedbugs cause much trouble. Although they are commonly found in congested districts where sanitary conditions are poor, yet they may be transferred at school from one child to another. Fortunately they are wingless and can be eradicated by available remedies.

The flea which may live upon the dog or the cat is not dangerous to us. But there is a flea distributed by the rat that is especially dangerous, since this insect carries the bacteria that cause *bubonic* (bů·bŏn′ĭk) plague. Hence care is taken at all large ports to prevent rats on ocean liners from coming ashore.

260. Have we other insect enemies? It will not be possible to discuss in detail other insect problems with which man has to deal. There are hundreds of species of insects injurious to crops, forests, other plants, or to animals. The potato beetle ruins potato plants unless controlled by Paris green; wheat is attacked by the Hessian fly; the corn crop is always menaced by the corn borer and the ear worm; almost every green plant has some of its juices sucked out by the plant louse, or *aphid* (ā′fĭd); elm trees in many sections have been ruined by the elm-tree beetle [see Fig. 18–15]; termites bore into wood not protected by creosote; the gypsy and brown-tail moths *defoliate* forests in New England.

In spite of the constant menace from injurious insects, it should be remembered that many biologists think that insects on the whole are more helpful than harmful.

Fig. 18–15. When elm trees are attacked by such insects as the elm-tree beetle, they must be carefully sprayed. It is not enough to spray the infected trees, however; every tree within the range of the pest must also be watched for an invasion. (*Courtesy Davey Tree Expert Co.*)

261. What animals are poisonous? In the minds of most persons there seems to be a great fear of poisonous snakes. It is true that rattlesnakes are widely distributed throughout much of this country. In the East there is also the copperhead, and in a few places in the South the coral snake and the water moccasin are found. One authority states: " In all the United States, the annual death rate from snake bite is insignificant." Today most communities keep on hand a fluid called *antivenin* (ăn′tĭ·vĕn′ĭn) which is used to treat snake bite. Antivenin, together with the proper first-aid outfit, should be carried if one is traveling in snake-infested territory.

There is only one spider in the country that is really dangerous and that is the black widow. This spider is all black except for a red cross or " hour glass " on the lower side of the body.

Scorpions have a sting in their tail which should be avoided, though it is not dangerous. There are some ticks that cause considerable trouble by their bite and because

they may distribute disease germs. The Texas-fever tick is a great menace to cattle in the South, causing an annual loss of about $60,000,000. Certain mites burrow beneath the human skin.

262. What are parasitic worms? Unfortunately, there are many kinds of worms which are likely to become parasites of human beings. The tapeworm and the *trichina* (trĭ·kī′nȧ), or pork worm, may be taken into the alimentary canal by eating infected meat which is not thoroughly cooked. If the tapeworm develops, it hangs itself to the inner wall of the intestine, sharing the food of its *host*. This is not necessarily fatal to the host, but the victim is likely to be undernourished. The trichina, on the other hand, when released in the human intestines, burrows through into the muscles of the victim. This is both painful and dangerous, and may be fatal. Both worms can be avoided by eating only inspected and carefully cooked meat. [See Fig. 18–16.]

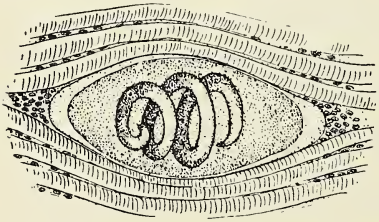


FIG. 18–16. This sketch shows a tiny trichina pork worm in the muscle of its host. What can you do to avoid being a host to such a parasite? (*Copyright by General Biological Supply House, Chicago*)

The hookworm pest enters the body of the victim by burrowing between the toes. It is then carried by the blood stream to the lungs, from which it makes its way up into the throat and thence down into the alimentary canal, finally lodging in the intestines. It is a fearful menace, sapping the vitality of its victims by sucking blood from the intestinal walls and frequently making these persons susceptible to tuberculosis. The Rockefeller Institute has eradicated the

hookworm in many places by teaching the residents to wear shoes, and to use proper sanitation and medication.

263. How can we keep the balance in nature? In many cases in the history of the world, men have made bad mistakes in completely eradicating certain animals or in introducing animals new to a certain territory. Nearly a dozen species of birds have been needlessly exterminated in this country for one reason or another. The rabbit was taken into Australia and became a terrible nuisance. The mongoose was introduced into many of the islands of the West Indies to control rats. It may have had some beneficial effect on the numbers of rats, though that has not been proved, but it is certain that the mongoose itself has become a worse pest than the rat ever was. In many of these islands there are now practically no wild birds, because this animal has killed the young in their nests. Chicken raising in these places is a difficult task. More than seventy-five of our worst insect pests were originally residents of other lands until they were accidentally introduced here.

264. Did the earliest settlers know and practice biology? This country was discovered and later settled by pioneers who had never studied biology. It is very natural that they should kill wild animals if they thought they were dangerous or if they found them valuable for food or for other purposes. They gave no thought to the possibility that the time might ever come when the fish that crowded the streams and lakes, the birds that came and went in flocks, or the other wild creatures that lived in the woods would begin to disappear because of the recklessness of unbiological man. So men fished and shot game and heedlessly cut down forests. [See Fig. 18–17.]

The day of reckoning has come. Many animals have already gone out of existence, never to return. No one will

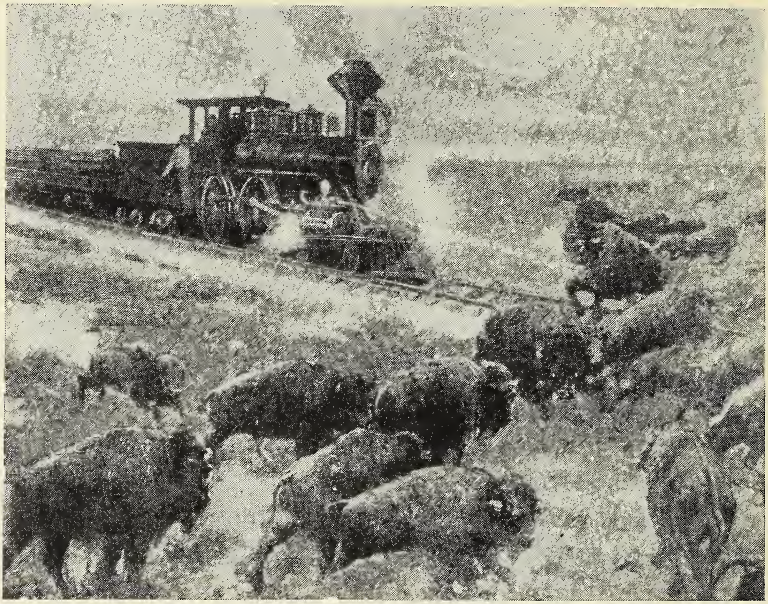


Fig. 18–17. The early Western trains sometimes had to fight buffaloes for right of way. This picture shows an engineer shooting steam at them to frighten them off of the tracks. Westward expansion of our country brought about the slaughter of so many buffaloes that they are now quite rare. (*Courtesy Association of American Railroads*)

ever again see a living passenger pigeon, or a great auk. If it had not been for public-spirited men, there would hardly be a single fish today in any fresh-water stream. If there had not been special *propagation* of certain wild forms under man's care, there would hardly be a chance of survival for many kinds of birds and game. Only a few years ago, Dr. Osborn, then president of the American Museum of Natural History, said "This is the age of vanishing wild mammals."

265. Who are the great conservationists? If we had not had in this country men of vision like President Theodore Roosevelt, Gifford Pinchot, John Burroughs, Henry Ford,

William Hornaday, Gilbert Pearson, and others like them, we might easily have lost most of our wild-life *heritage*. Theodore Roosevelt, when he was President of the United States, started a great conservation movement. This was joined and carried forward by the governors of the different states whom he called together, and public opinion finally was crystallized in many different laws protecting our wild birds and many of the other wild forms. [See Fig. 18–18.]

266. What are the most important conservation laws concerning birds? There are two most important conservation laws relating to birds. The first is the law of 1915, preventing the importing into this country of the plumage of wild birds. This closed the market in the United States for feathers of foreign birds, formerly used as ornaments on hats. The second law, also a federal law, and of even more value, is the Migratory Bird Act. This law, adopted also by Canada in 1929, protects all wild birds, except the crow, English sparrow, and a few others, from the Gulf of Mexico to the Arctic Ocean, in every state of the United States and in all the provinces of Canada.

267. What conservation laws deal with fish and mammals? Fishermen may pursue their favorite sport in certain *open*, or unrestricted, seasons only, not at any time, which might be the breeding period of fishes. Fish may be caught legally only if they are of a certain size, and more than a certain number may not be caught. Even stricter laws have been passed to protect our vanishing wild mammals.

268. Who enforces these conservation laws? The Biological Survey represents the United States in this conservation work. In addition practically every state has its own fish, forest, and game commission or conservation commission to enforce the laws within its own borders. There are hundreds of state and federal game wardens.

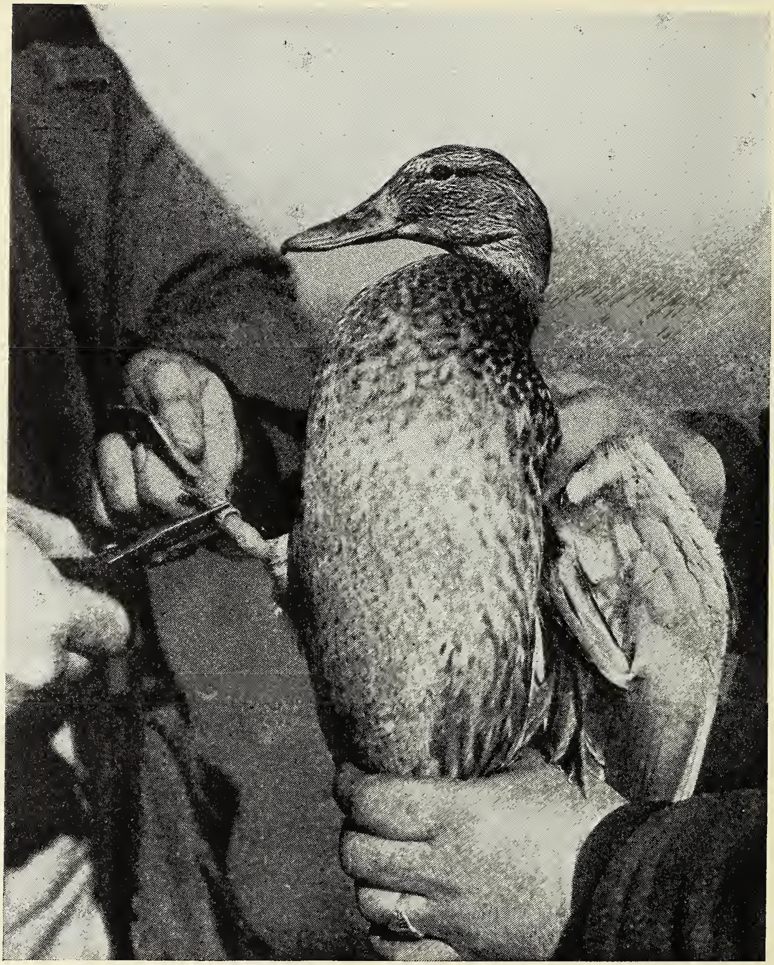


FIG. 18–18. The picture shows a wild duck being banded by members of the Bureau of Biological Survey. Birds are banded by having loosely attached to them a small aluminum band, bearing a number. This number is recorded and the bird is released. When a bird is found bearing such a band, the finder should report the number on it and the place where it was found to the Bureau of Biological Survey. In this way we can all learn more about the travels of birds. (*Courtesy U. S. Bureau of Biological Survey*)

269. Are there good results? The conservation movement has already brought about an increase in the numbers of wild birds. Fish commissions have planted millions of young fish in streams and lakes. Fishermen, hunters, and naturalists all recognize the great benefits coming from this conservation program. You, too, can help by obeying the laws, and by helping others to realize their value to all.

270. Is wild life a national asset? Dr. William Hornaday, when Director of the New York Zoological Park, said a profound truth which at last is being acknowledged. He said, over and over again, that the wild life of America does not belong to one generation, but is a national heritage which belongs to all, even to generations as yet unborn.

As one reviews the many relations of animals to man, one begins to realize that modern civilization could not be maintained without the animals of the world. It is a wise man who, instead of selfishly destroying wild life, controls injurious species and conserves helpful forms in co-operation with the millions of other conservationists.

Questions

1. List all the animal products which you ate last week. Can you name the animal which was the source of each product?
2. Can you name six different kinds of furs? What are they?
3. Which fur is the most costly? Why?
4. Is it true that durable leather has been obtained from snake skin and lizard skin? Can you name any other strange leathers?
5. What animals are still used as beasts of burden in different parts of the world?
6. Why do we not see the feathers of wild birds as ornaments on women's hats in this country?
7. Do you know what has been called the most dangerous mammal in the United States?
8. How can the fly and the mosquito be controlled?

9. Why should the fly and the mosquito be controlled?

10. How were the orange trees in California saved from scale insects?

11. Do you think that insects are more harmful or more helpful to mankind? Give reasons.

12. How are pearls produced? Use an encyclopedia or other reference book to find out.

13. Can you give reasons why it pays to protect wild birds?

14. Why are harmless snakes and toads valuable?

15. Would it be valuable for a man with an orchard to have bees? Can you explain why?

16. What household pests, other than the fly and the mosquito, can you mention?

17. What is the conservation movement and how can you aid it?

Some things for you to do

1. Find out what Theodore Roosevelt did for the cause of conservation, especially while he was President of the United States. Put these facts into a brief report.

2. Write to the Department of Agriculture for a pamphlet on the raising of fur-bearing animals such as foxes, mink, and skunks.

3. Start a check-list of migrating birds.

4. Watch the nest of a pair of robins or a pair of bluebirds or some other birds in the late spring or early summer. After the young birds hatch, note how many times one or the other of the parent birds visits the nest with food for the young.

5. Photograph a wild bird at a bird bath. First focus your camera, then conceal it. Release the shutter by pulling a long thread which has been attached to it.

6. Make a collection of insects which you find eating plants in your own garden or in a neighbor's garden.

7. Make a list of fly- and mosquito-breeding places in your neighborhood. See if your class at school can do something to prevent the multiplication of these two injurious insects.

8. Explain how you have tamed an animal or taught an animal a trick.

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Glossary

ABSORB, to suck up or take in.

ABSORPTION (ăb·sôrp′shŭn), the passing of soluble substances through membranes and into cells.

ADAPTATION (ăd′ăp·tā′shŭn), a part, or structure, of a living organism, fitted to perform some function.

AËDES (ȧ·ē′dēz), the mosquito which frequently acts as a carrier of yellow-fever germs.

AGENT, a power, force, or means by which something is accomplished; some person or thing which acts for another.

ALGAE (ăl′jē), flowerless plants, including most seaweeds and many kinds of fresh-water plants.

ALIMENTARY (ăl′ĭ·mĕn′tȧ·rĭ) CANAL, the tube in which food is digested.

ALTIMETER (ăl·tĭm′ė·tĕr), an instrument for measuring altitude.

ALTITUDE, height or elevation.

AMOEBA (ȧ·mē′bȧ), one of the simplest known animals, consisting of only one cell.

ANATOMY, the science dealing with the structure of plants and animals.

ANOPHELES (ȧ·nŏf′ĕ·lēz), the mosquito which may act as a carrier of malaria germs.

ANTHRACITE, hard coal.

ANTIVENIN (ăn·tĭ·vĕn′ĭn), a serum used as an antidote for snake bites.

APHID (ā′fĭd), a sucking insect known as the plant louse.

AQUATIC (ȧ·kwăt′ĭk), living in, or belonging to, water.

AQUEOUS (ā′kwė·ŭs), watery.

ARGON (är′gŏn), a very inactive element found in the air.

AROMATIC (ăr′ō·măt′ĭk), having a pleasant odor.

ASBESTOS (ăs·bĕs′tŏs), a mineral used to make various fireproof articles.

ASEXUAL (ȧ·sĕk′shōō·ăl), without sex; used to describe reproduction without eggs and sperms in both plants and animals.

ASH, mineral matter left after burning is completed.

ASSIMILATION (ă·sĭm′ĭ·lā′shŭn), the changing of food into the protoplasm of cells.

ASTRONOMY (ăs·trŏn′ō·mĭ), the science dealing with the study of stars and other heavenly bodies.

Atom, the smallest particle of matter with which the chemist deals in chemical changes.

Aurora borealis (ô·rō′rȧ bō′rē·ā′lĭs), *northern lights;* lights sometimes seen in the sky, most clearly in the arctic regions.

Automatically, acting of its own accord; without an agent.

Bacterium (băk·tēr′ĭ·*ŭ*m), plural Bacteria, a single cell of certain one-celled flowerless plants.

Barometer (bȧ′rŏm′ē·tẽr), an instrument used to measure air pressure.

Biology, the science of living things.

Bituminous (bĭ·tū′mĭ·n*ŭ*s) coal, soft coal.

Blood vessels, tubes which carry the blood throughout the body.

Botany, the science dealing with the study of plant life.

Braille (brāl), a system of printing for the blind in which characters are represented by raised dots.

Bulb, a compact form of underground stem.

Burning, the uniting of oxygen with some other substance so rapidly that both light and heat are produced.

Calorie (kăl′ō·rĭ), the unit used in the metric system to measure heat.

Cambium, the outer region in a woody stem where growth takes place.

Capillaries (kăp′*ĭ*·lẽr·ĭz), the smallest blood vessels in the body.

Carbon dioxide (kär′b*ŏ*n dī·*ŏ*k′sīd), a colorless gas, present in the atmosphere. It is a source of food for plants.

Carbon monoxide, a colorless, poisonous, flammable gas formed by the incomplete combustion of carbon.

Carburetor (kär′bū·rĕt′ẽr), an apparatus used to change liquid gasoline into gasoline vapor and to mix it with air.

Carcass, the dead body of an animal.

Cell, the simplest unit of structure of which plants and animals are composed.

Cellular, referring to the cells of a particular part of a plant or animal.

Cellulose (sĕl′ū·lōs), the woody fiber that forms the walls of the cells of plant tissue.

Centigrade (sĕn′t*ĭ*·grād), the name applied to that thermometer scale on which the space between the freezing point and the boiling point is divided into 100 degrees.

Chemistry, the science that deals with chemical changes and the composition of substances.

Chlorophyll (klō′rō·fĭl), the green coloring matter of most plants.

Circuit (sûr′kĭt), the complete path of an electric current.

Circulation, the movement of liquids, chiefly blood in animals, throughout the structure of a living organism.

Cirrus (sĭr′ŭs) cloud, a light, fleecy cloud.

Classify, to arrange in an orderly manner in sets or groups.

Coke, the solid residue left after heating soft coal.

Cold-blooded, having a body temperature which varies with the temperature of the surroundings.

Colonial (kŏ·lō′nĭ·ăl), living together in a group.

Colony, a group of many individuals, usually of the same kind, living together.

Combustion, the act of burning.

Composition (kŏm′pŏ·zĭsh′ŭn), all the substances of which a thing is made up or composed.

Compound, a substance consisting of two or more elements chemically combined.

Compression pump, a pump which is used to squeeze or to compress gases.

Condensation (kŏn′dĕn·sā′shŭn), the process in which a vapor (usually water vapor) is changed into a liquid.

Conductor, a substance through which heat or electricity can easily pass.

Conservation (kŏn′sĕr·vā′shŭn), preserving in a natural state or saving from destruction.

Control, an experiment set up to check the results of another experiment.

Cover crop, a crop of plants whose roots keep the soil from being washed away.

Crossing, mating two possible parents with the purpose of producing offspring.

Cross-pollination, the depositing of pollen from one flower upon the pistil of another flower of the same kind.

Crown, the upper leafy part of a tree.

Culex (kū′lĕks), the common mosquito.

Cumulo-nimbus (kū′mū·lō nĭm′bŭs) cloud, a large dark cloud from whose base falls snow, showers of rain, or sleet.

Cusp, a sharp edge on the crown of many of the teeth of animals such as the dog, cat, bear, and lion.

Deciduous (dė·sĭd′ū·ŭs), having leaves that fall at the approach of winter.

Decomposition, the process of breaking up a compound into its elements.

DEFOLIATE (dē·fō′lĭ·āt), to strip the leaves from.

DEHYDRATED (dē·hī′drāt·ĕd), freed of all water, as dried fruit, for example.

DENSITY, the weight of one unit volume of a substance; one cubic foot, for example.

DEPOSIT, to lay down, or to leave, as evaporating water leaves some substance which has been suspended or dissolved in it.

DIFFUSED (dĭ·fūzd′), scattered like rays of light by particles of dust.

DIGESTION, the changing of a food substance into such a form that it can be used by organisms either to make more cells or to give energy.

DILUTE (dĭ·lūt′), reduced in strength, as by the addition of water.

DINOSAUR (dī′nō·sôr), a prehistoric animal related to modern reptiles.

DISINTEGRATING (dĭs·ĭn′tē·grāt′ing), being reduced to fragments or particles.

DRUMLIN (drŭm′lĭn), an oval hill consisting of earth and rocks deposited by a glacier.

DUCT, a tube in plants used to carry liquids through the plant.

ECONOMIC, relating to the satisfaction of man's needs.

ELEMENT, a substance which is not split up into simpler substances by chemical change.

EMBRYO (ĕm′brĭ·ō), a very young animal, before it is hatched or born; applied also to the young plant in a seed.

ENERGY, the capacity to do work.

ENTOMOLOGY (ĕn′tō·mŏl′ō·jĭ), the science dealing with the study of insects.

ENVIRONMENT (ĕn·vī′rŭn·mĕnt), all the surrounding conditions or influences that affect the life of the individual.

EROSION (ē·rō′zhŭn), the wearing away of rock or soil by such forces as wind and water.

ESKER, a ridge formed by the depositing of soil beneath the ice of a glacier.

EVAPORATE, to change from a liquid to a vapor or a gas.

EXCRETE (ĕks·krēt′), to pass off, especially referring to wastes from animals.

EXHAUST, as used here, to remove the air from, or to create a vacuum in.

EXPERIMENT (ĕks·pĕr′ĭ·mĕnt), a test or trial to learn the truth about something of which we are ignorant, uncertain, or doubtful.

EXPLOSION, oxidation which occurs almost instantaneously.

EXTERNAL FERTILIZATION, fertilization of the egg outside the body of the parent.

FAHRENHEIT (făr'ĕn·hīt) THERMOMETER, the thermometer commonly used in the United States. It is so graduated that the freezing point of water is marked 32° above zero, and the boiling point of water is marked 212° above zero.

FALL LINE, the boundary between a higher region, or plateau, and a lower, coastal plain. At this boundary there are likely to be falls in a river, so that ships cannot pass farther up the river.

FELDSPAR, any of a group of minerals which, in decomposing, add clay to the soil. Feldspar is one of the minerals of which granite is composed.

FERMENTATION, a chemical change produced by yeast or some similar substance called a ferment.

FERTILIZATION, the union of the nucleus of a male reproductive cell with the nucleus of a female reproductive cell.

FIBER, a slender, threadlike part of a substance.

FILAMENT, the slender stem of a stamen in a flower; a slender, threadlike part such as the filament of an electric light bulb.

FISSURE (fĭsh'ûr), a crack or crevice in the earth's crust.

FLAMMABLE, referring to things that burn readily. It has the same meaning as *inflammable*.

FLOWER, the colored, showy part of a seed plant consisting usually of calyx, corolla, stamens, and pistil.

FLUE, a chimney, or a metal or earthenware pipe, used for carrying away hot gases and smoke.

FOCUS, that point at which rays of light from an object meet as they are bent in passing through a lens.

FORCE, muscular effort, or something that produces the same effect; a push or a pull.

FOSSIL, any impression or trace of an animal or a plant of past geological ages, which has been preserved, usually in sedimentary rocks.

FRICTION, the resistance to motion. Friction causes heat.

FRUIT, a ripened ovary of a seed plant and its contents, together with any closely connected parts.

FUNCTION (fŭngk'shŭn), use or action; one of the basic activities of a plant or an animal.

FUSE, a special wire used in an electric circuit. It melts when there is a short circuit or an overloading of the wire caused by the use of too many electrical appliances at one time.

GALVANIZED IRON, iron or steel coated with zinc to protect it from rust.

GAUGE (gāj), an instrument used for measuring.

GEOLOGY, the science dealing with the history and composition of the earth.

GEYSER (gī′zẽr), a spring which throws out boiling water and steam at intervals.

GILA (hē′lȧ) MONSTER, a large lizard found in the southwestern United States and in Central America.

GILLS (gĭlz), organs for breathing under water.

GLACIER (glā′shẽr), a field or body of ice, formed in a region where snow falls in great quantities and more rapidly than it can melt.

GRADUATED, (of a thermometer) marked off into degrees.

GRAM, the unit of weight in the metric system. There are 454 grams in one pound.

GRANITE, a very hard, durable rock which takes a fine polish.

GROUND WATER, water within the earth, which supplies wells and springs.

GRUB, the wormlike stage following the egg in the life history of such insects as the beetle, fly, butterfly, and others.

HEART, the organ which pumps the blood and causes it to circulate through the body of an animal.

HEARTWOOD, the hard, matured wood of the central part of a woody stem; usually considered as dead tissue.

HELIUM (hē′lĭ·ŭm), a very light element found in the air in small quantities.

HERITAGE (hĕr′ĭ·tĭj), a possession by birthright.

HORIZON (hȯ·rī′z′n), the line where the sky and earth seem to meet.

HORMONE (hôr′mōn), a substance secreted by a gland in the body. Hormones are necessary for growth and health.

HORNBLENDE (hôrn′blĕnd), an igneous mineral, usually black, dark green, or brown.

HORNS, hard growths, or structures, on the head of certain animals.

HOST, the animal or plant on which a parasite lives.

HUMUS (hū′mŭs), the dark brown or black part of the soil, which has been formed by decaying plant or animal life.

HYBRID, an offspring from the mating of two parents having contrasting unit characters.

HYDROGEN (hī′drȯ·jĕn), a gas, the lightest substance known.

HYDROPONIC (hī′drȯ·pŏn′ĭk) CROPS, crops grown in water containing chemicals, instead of in soil.

ICHNEUMON (ĭk·nū′mŏn) FLY, a small insect, the female of which lays her eggs in the bodies of tent caterpillars, and other insects, and thus destroys them.

IGNEOUS (ĭg'nė·ŭs), resulting from the action of intense heat.

IGNITE (ĭg·nīt'), to take fire.

IMMUNE, not subject to; free from.

INCANDESCENT (ĭn'kăn·dĕs'ĕnt), heated until it glows.

INCUBATION (ĭn'kū·bā'shŭn), the process of keeping eggs warm as a bird or chicken does, by setting on them.

INFLATE, to enlarge by crowding in more air or gas.

INTERNAL FERTILIZATION, fertilization of an egg within the body of the parent.

INTRUSION, as used in geology, the forcing of masses of molten rock between layers of rock.

INVERTEBRATE, an animal having no vertebrae or backbones; sometimes called the lower animals.

IODINE (ī'ō·dīn), a substance used in medicine as an antiseptic. It is sometimes extracted from seaweeds.

KAME, a short ridge, formed by a stream flowing under a glacier.

KILN (kĭl), an oven much used in industrial operations, to harden, burn, or dry some material, as brick, or to produce glazing on pottery.

KINDLING TEMPERATURE, the lowest temperature at which a substance begins to burn.

LARVA (lär'vȧ), plural LARVAE (lär'vē), the second stage in the life of an insect, following the egg.

LATEX (lā'tĕks), the whitish sap of the rubber tree.

LAVA (lä'vȧ), liquid or melted rock, usually found associated with a volcano.

LEAF, a part of most plants, broad, flat, and thin, generally growing out of the stem; it is ordinarily green in color, due to chlorophyll, with which it manufactures starch.

LEGUME (lĕg'ūm), a kind of plant, such as the pea, bean, alfalfa, and clover; it is valuable as a soil-enricher because of the nitrogen-fixing bacteria on its roots.

LEVEE (lĕv'ė), an embankment which holds back water or floods.

LEVER (lē'vẽr), a bar which may move freely about a fixed point, or fulcrum.

LIGHT, that form of radiant energy which affects the optic nerve and causes the sensation known as sight.

LIMESTONE, a sedimentary rock, composed of deposits of calcium carbonate.

LOCOMOTION, the moving about of an organism from place to place.

LUNG, a breathing organ, found in pairs in air-breathing vertebrates.

MACHINE, a device used to transfer or change energy.

MAGGOT, a soft-bodied, footless larva of a fly.

MAMMAL, a member of the highest group of animals, whose young are born alive and are nourished by the milk of the mother animal.

MARBLE, a rock, formerly limestone, but changed by heat and pressure into a finer-textured stone.

MASTODON (măs′tô·dŏn), an elephant-like animal, now extinct.

MATTER, anything that takes up room or occupies space.

MEDICINE, the science dealing with the prevention, cure, and alleviation of disease.

MEMBRANE (mĕm′brān), a thin, soft sheet or layer, of plant or animal origin, resembling thin skin.

MEMBRANOUS (mĕm′brȧ·nŭs), thin, like skin.

METEOROLOGY, the science dealing with the study of the weather.

METER, the unit of length in the metric system. A meter equals 39.37 inches.

MICA (mī′kȧ), a mineral, capable of being separated into very thin sheets.

MICROSCOPE (mī′krô·skōp), an instrument by means of which small things are magnified.

MINERAL, any fairly pure substance, not a direct product of a plant or an animal, found in the rocks of the earth.

MOLECULE, (mŏl′ē·kūl), the smallest particle into which matter can be divided without losing its identity.

MOLLUSK (mŏl′ŭsk), any of a group of soft-bodied animals usually having a shell, such as the oyster or snail.

MORAINE, an accumulation of earth and rock carried, and finally deposited, by a glacier.

MULCH (mŭlch), material, such as straw or leaves, used as a covering for plants in the winter.

NAPHTHA (năf′thȧ), a petroleum product, like benzine and gasoline.

NECTAR, a sweet liquid produced by most flowers.

NEON (nē′ŏn), an element found in the air. There is only about one part of it in from 20,000 to 40,000 parts of air.

NITRATE (nī′trāt), a compound of nitrogen and other elements. It is used as a fertilizer.

NITROGEN (nī′trô·jĕn), a gas which makes up about four-fifths of the earth's atmosphere by volume.

NITROGLYCERINE (nī′trô·glĭs′ĕr·ĭn), a liquid which explodes violently when it is made to vibrate or is heated very highly.

NODULES (nŏd′ūlz), little knots on the roots of plants such as clover,

peas, and beans. They contain bacteria which take nitrogen from the air and make compounds of it.

NUCLEUS (nū'klē·ŭs), the most important part of a cell, frequently ball-like in shape.

ORE, a natural mineral from which a useful element or metal may be profitably extracted.

ORGAN, a part, or structure, of an animal or plant, fitted for some special purpose. The heart and the leaf are examples of organs.

OSMOSIS (ŏs·mō'sĭs), the passing of a fluid through a wet, thin membrane.

OVA, singular OVUM, eggs; the female reproductive cells.

OVARY (ō'vȧ·rĭ), in a plant, the part at the base of the pistil in which the seeds grow; in an animal, the female reproductive organ which produces the eggs.

OVULE (ō'vūl), the beginning of a seed before fertilization; an unripe, or undeveloped, seed. An ovule is the female reproductive cell in a seed plant.

OXIDATION (ŏk'sĭ·dā'shŭn), the combining of oxygen with some other substance.

OXIDE, a compound containing oxygen and some other element.

OXYGEN (ŏk'sĭ·jĕn), the most abundant element in the world.

PARAFFIN (păr'ă·fĭn), a waxy substance, obtained from petroleum.

PARASITE (păr'ȧ·sīt), an animal or a plant which lives on and obtains its nourishment from another animal or plant.

PETAL, one of the parts of the corolla of a flower; it is usually brightly colored and attracts pollinating insects.

PETROLEUM (pē·trō'lē·ŭm), an oily, flammable liquid, usually dark brown or green in color, found in many places below the soil; from it we get fuels (gasoline, benzine, naphtha) and lubricants (oil and grease).

PHILOSOPHER (fĭ·lŏs'ō·fẽr), a thinker who seeks causes and studies relationships and results.

PHOSPHATE (fŏs'fāt), a combination of phosphorus and other elements. It is used as a fertilizer.

PHOSPHORUS (fŏs'fō·rŭs), a chemical element needed for the growth of living things.

PHYSICS, the science of matter and energy.

PHYSIOGRAPHY (fĭz'ĭ·ŏg'rȧ·fĭ), the science dealing with the surface of the earth and the changes on it caused by winds, earthquakes, waves of the ocean, and other forces.

Physiology (fĭz′ĭ·ŏl′ṓ·jĭ), the science of the functions of living organs.

Pistil, the tall, central part of a flower, which includes the ovules. It is the female reproductive organ of a seed plant.

Pith, the soft tissue found in the center of woody stems.

Planaria (plȧ·nâr′ĭ·ȧ), a small, soft-bodied, leaf-shaped worm, usually found in water.

Planet, any body, except a comet or a meteor, that revolves around the sun in our solar system.

Pollen, small grains, or cells, which are formed on the stamens of a flower. They are the male reproductive cells of a seed plant.

Potash (pŏt′ăsh′), a substance obtained from wood ashes and used in fertilizers.

Potassium (pṓ·tăs′ĭ·ŭm), a chemical element necessary for the proper growth of plants.

Precipitation, a deposit in the air, on objects, or on the earth, of mist, rain, hail, sleet, or snow.

Preservative, an agent that prevents decay.

Pressure, a force which may cause a push or a pull.

Propagation (prŏp′ȧ·gā′shŭn), reproduction, under man's care, of organisms.

Properties, the qualities or characteristics of some particular substance.

Protein (prō′tḗ·ĭn), a food substance necessary for the making of protoplasm.

Protoplasm (prō′tṓ·plăz′m), the parts of a cell that show life; the physical basis of all life.

Psychologist (sī·kŏl′ṓ·jĭst), a person who is skilled in the science dealing with the study of the mind.

Pumice (pŭm′ĭs), a light, spongy rock that is formed from lava.

Pupa (pū′pȧ), plural Pupae (pū′pē), the stage in the life of an insect that precedes the adult stage. It follows the larva.

Quartz, a common mineral of great hardness.

Quiescent (kwī·ĕs′ĕnt), quiet or nonexplosive.

Quinine (kwī′nīn), a white crystal obtained from the bark of cinchona trees; it is used as a medicine, chiefly in the control of malaria.

React, to respond.

Refinery, a plant for refining, or purifying substances, especially metals (iron), oils, and sugars.

Reflected, turned back, as when a sound is echoed.

Reforestation (rē′fŏr·ĕs·tā′shŭn), the reseeding or planting of young trees in an area from which trees have been removed.

Refuse (rĕf′ūs), something which has been discarded as useless or worthless; wastes from digested food, passed off from the alimentary canal.

Reproduce (rē′prȯ·dūs′), to have offspring.

Reservoir (rĕz′ẽr·vwôr), a storage place, generally for water; in plants the part where food is stored.

Rind, the skin or outer coat of a plant or some part of a plant.

Rodent, a member of the group of animals known as Rodentia, characterized by four prominent incisor teeth for gnawing.

Root, that part of a plant which is usually underground; it absorbs water and minerals, stores food, and helps to support the plant.

Runner, a stem which lies on the ground; from its joint, roots for a new plant may grow. Strawberries reproduce by runners.

Saliva (sȧ·lī′vȧ), a digestive juice produced in the mouth of all higher vertebrates.

Sandstone, a rock made largely of particles of sand cemented together.

Scale, a small, flattened structure; a kind of flat, legless insect.

Science, knowledge gained or verified by exact observation and experiment.

Secrete (sė·krēt′), to make or separate substances within the body structure of a plant or an animal.

Secretion (sė·krē′shŭn), a substance which is secreted, or given off, by a cell or cells; its source is usually the blood in animals.

Section, a thin slice.

Sediment (sĕd′ĭ·mĕnt), material which is usually deposited by water.

Sedimentary (sĕd′ĭ·mĕn′tȧ·rĭ) rock, rock which has been formed mainly of materials deposited by water.

Seedling, a young plant just after sprouting from the seed.

Seep, to run or leak through.

Serum (sēr′ŭm), a substance obtained from the blood of an animal made immune to a certain disease; it is used to cure or to prevent this disease in human beings.

Sexual reproduction, reproduction by the union of an egg and a sperm; reproduction in which two parents take part.

Shale (shāl), a rock formed from clay that has been pressed together with great force.

Sieve tube, a plant structure in the bark of woody plants through which food passes down the stem.

Silt, fine sediment carried in, or deposited by, water.

Sink hole, a round depression, or hollow, originally filled with glacial snow and ice, and left when the glacier melted.

Siphon (sī′fŏn), a tube by means of which a liquid may be transferred by atmospheric pressure from one container to another.

Sisal (sī′săl), a plant with a strong white fiber, three to five feet long; it is used for making twine and rope.

Sizing (sīz′ĭng), the act or process of applying size, or glaze. *Size* is a substance, such as flour, glue, varnish, or shellac, used to fill the pores, or holes, in wood, paper, or plaster.

Slate, a fine-grained rock which was once clay or shale, but has since become metamorphized, or changed by heat and pressure in the earth.

Slip, a small plant shoot or twig, cut off for planting or grafting.

Solute (sŏl′ūt), the salt or other substance dissolved in a liquid to make a solution.

Solution, a liquid in which some substance has been dissolved.

Solvent (sŏl′vĕnt), a substance which is capable of dissolving, or helping to dissolve, another substance.

Spall (spôl), a fragment of broken rock.

Species (spē′shiz), a group of animals or plants with certain common characteristics.

Specimen, an individual.

Sperm (spûrm) cells, the male cells which fertilize the ova, or eggs.

Spontaneous (spŏn·tā′nē·ŭs), acting of its own accord, without apparent outside urge or aid.

Spore, a small cell by means of which certain flowerless plants — molds, for instance — reproduce. In function a spore corresponds to a seed.

Sport, a new kind of plant or animal which comes into existence in nature. It is unlike its parents in certain characteristics which appear in its offspring.

Stag, the male deer.

Stalactite (stȧ·lăk′tīt), a calcium carbonate formation, resembling an icicle, hanging from the roof of a cavern.

Stalagmite (stȧ·lăg′mīt), a calcium carbonate formation rising, like an inverted stalactite, from the ground of a cavern.

Stamen (stā′mĕn), a threadlike part of a flower on the top of which pollen is formed.

Stem, the part of a plant which supports leaves and flowers, if present, and through which water, food, and secretions are transported.

Stethoscope (stĕth′ō·skōp), an instrument for listening to the physiological sounds of the body, especially of the chest.

Stoma (stō′mȧ) plural Stomata (stō′mȧ·tȧ), one of the many openings in a leaf, usually found in the lower surface.

STRATA (strā′tȧ), layers.
STRATIFICATION (străt′ĭ·fĭ·kā′shŭn), the process of depositing material in strata, or layers.
STRATOSPHERE (strā′tō·sfēr), the portion of the atmosphere above the highest clouds.
STRUCTURE, the parts that make up a physical thing or an organism; the way in which something is built up.
SUBSTANCE, the material of which a thing is made.
SUPERSTITION (sū′pēr·stĭsh′ŭn), a mistaken belief; or an excessive fear of, or reverence for, the unknown or the mysterious.

TALC, a soft mineral, with a soapy texture.
TANNING, changing the skin of an animal to leather, by means of a chemical process.
TENTACLE (tĕn′tȧ·k′l), a slender part of certain low animals, capable of motion in any direction.
TESTES (tĕs′tēz), the organs in an animal which produce male cells.
TEXTURE, hardness or softness of a tissue or part.
THEORY, a reasonable explanation of some natural happening. A theory is an idea which has not yet been, or cannot be, entirely proved by experiment in a laboratory.
THRUST, a push, such as is exerted by some force below the surface of the earth.
TINDER, material of low kindling temperature.
TORNADO, a whirling windstorm of great violence.
TOXIN (tŏk′sĭn), a poison produced by a plant or an animal.
TRANSPIRATION, the passing off of water vapor from the leaves of a plant.
TRICHINA (trĭ·kī′nȧ), a small worm, a parasite in the larval stage, which lives in the muscles of man, hog, or other animals.
TRILOBITE (trī′lō·bīt), an extinct marine animal, from an inch to a foot in length, now found in fossilized form.
TUNGSTEN (tŭng′stĕn), an element of the chromium family, widely used in electric-light filaments.
TYPICAL, representing the average of a group of things or individuals.

URINE (ū′rĭn), the watery waste secreted by the kidneys and excreted from the bladder in the higher animals.
UNIT, a common part or a common measure.

VACCINE (văk′sēn), a substance developed by man, usually in a cow, to combat a disease.

Vacuum, a space that does not contain any air or other matter.

Valve, a device which permits a substance to flow in one direction only.

Vapor (vā′pẽr), a substance in the form of a gas.

Velocity (vē̇·lŏs′ĭ·tĭ), the rate of motion, or the speed.

Vertebra (vûr′tē̇·brȧ), plural Vertebrae (vûr′tē̇·brē), one of the small bones in the spine.

Vertebrate (vûr′tē̇·brȧt), one of the higher animals having a spine, or a spinal column.

Volume, the amount of space occupied by something.

Volvox, a microscopic organism found in fresh-water ponds, claimed by botanists as a plant, and by zoologists as an animal.

Vulcanization, the act or process of treating crude rubber with sulfur to make it less sticky or less brittle.

Warm-blooded, having a body temperature which is relatively high and constant, usually considerably above that of the surroundings; a relatively high rate of oxidation within the body cells.

Water cycle, the repeating process in which water from oceans, lakes, and rivers becomes water vapor; then is pushed upward into cooler air and condenses into water again and falls to the earth.

Water table, the level at which the water stands in the ground.

Zoology (zō̇·ŏl′ō̇·jĭ), the science dealing with the study of animals.

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